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Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control
Volume II. Yakima Valley Case Study

Colorado State Univ., Fort Collins

Prepared for

Robert S. Kerr Environmental Research Lab., Ada, OK

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Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control

Volume II
Yakima Valley
Case Study

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The goal of this research project has been to develop an effective process for implementing technical and institutional solutions to the problem of irrigation return flow pollution. This report contains the findings of a case study of the Yakima Valley, Washington. The findings are reported according to the proposed process, namely: a) defining the problem in terms of its physical, legal, economic, and social parameters; b) identifying potential solutions in relation to the key parameters of the problem; c) assessing the range of potential solutions for the specific area of concern; and d) specifying those solutions or groups of solutions which are most effective in reducing pollution and are implementable.

The basic conclusions of the report are that: a) irrigation methods used in many parts of the Valley are inappropriate to the topography and soils, thus causing return flow pollution; b) neither state nor federal water quality regulations have had a significant impact on the pollution problem; c) a major cause of the problem is the underpricing of irrigation water caused by the absence of economic markets for its allocation; d) the first step in solving the problem is the creation of an economic market to allocate irrigation water; e) perception and demonstration of the problem are vital for any efforts to implement any solutions; and f) holistic thinking by farmers regarding water in the Valley and individual acknowledgment of contributions to the problem are necessary to its solution.

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: a) investigate the nature, transport, fate, and management of pollutants in ground water; b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; c) develop and demonstrate pollution control technologies for irrigation return flows; d) develop and demonstrate pollution control technologies for animal production wastes; e) develop and demonstrate technologies to prevent, control, or abate pollution from the petroleum refining and petrochemical industries; and f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar

William C. Galegar
Director
Robert S. Kerr Environmental
Research Laboratory

PREFACE

This report concentrates on the presentation of a process for implementing technical and institutional solutions to the problem of return flow pollution. This process, under the general title of "Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control," was centered around a methodological and pragmatic definition of the problem and identification and assessment of a wide range of potential solutions for diverse situations. Four separate, but interrelated, volumes summarize the study:

Volume I -- Methodology (Main Report)
Volume II -- Yakima Valley Case Study
Volume III -- Middle Rio Grande Valley Case Study
Volume IV -- Grand Valley Case Study.

Volume I (the main report) summarizes the overall research approach of the study; the methodological premises; the nature of the problem; the process for identifying and assessing appropriate solutions; and, some general remarks and conclusions concerning the process of implementation. Volumes II to IV allow for an in-depth presentation of the approach utilized as well as specific findings and recommendations relating to the problems of each case.

The interdisciplinary team has also prepared a separate "executive summary" which is quite a shortened version and with the help of accompanying illustrations attempts to provide in a succinct form the major findings of the study as well as the propositions involved in the identification, assessment and evaluation of potential solutions concerning irrigation return flow.

ABSTRACT

The goal of this research project has been to develop an effective process for implementing technical and institutional solutions to the problem of irrigation return flow pollution. This report contains the findings of a case study of the Yakima Valley, Washington. The findings are reported according to the proposed process, namely: a) defining the problem in terms of its physical, legal, economic and social parameters; b) identifying potential solutions in relation to the key parameters of the problem; c) assessing the range of potential solutions for the specific area of concern; and d) specifying those solutions or groups of solutions which are most effective in reducing pollution and are implementable.

The basic conclusions of the report are that: a) irrigation methods used in many parts of the Valley are inappropriate to the topography and soils, thus causing return flow pollution; b) neither state nor federal water quality regulations have had a significant impact on the pollution problem; c) a major cause of the problem is the underpricing of irrigation water caused by the absence of economic markets for its allocation; d) the first step in solving the problem is the creation of an economic market to allocate irrigation water; e) perception and demonstration of the problem are vital for any efforts to implement any solutions; and f) holistic thinking by farmers regarding water in the Valley and individual acknowledgment of contributions to the problem are necessary to its solution.

This report was submitted in fulfillment of Grant No. R-803572 by Colorado State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period between February 14, 1975, to November 14, 1977, and work was completed as of May 4, 1978.

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The authors are deeply indebted to the many farmers, state water resource agency personnel, and many in their capacity as managers and directors of irrigation districts and companies in the various states, who provided invaluable information to the team members during interviews and in supplying reports and data.

SECTION 1

INTRODUCTION

The general goal of this research project has been the development of a basis leading to an effective process for implementing technical and institutional solutions to the problem of irrigation return flow pollution. The present report, based on a case study analysis of Yakima Valley, Washington, contains specific findings per the proposed process, namely: a) defining the problem in its physical, legal, economic, and social parameters; b) identifying potential solutions in relation to key parameters of the problem; c) assessing the range of potential solutions for the specific area of concern; and d) specifying those solutions or groups of solutions which are most effective in reducing pollution and are implementable.

As stated in the main report, the approach and emphasis of the overall project, and of all case studies as well, does not rest exclusively on the determination of an "appropriate solution" for the problem of return flow, although the last is a central point in communicating effectively the spirit of PL 92-500. The concern throughout begins with the process of arriving at appropriate solutions, in assessing in an interdisciplinary manner, and in outlining the steps for an eventual process of implementation of whatever may be the agreed-upon "solution" or program.

Finally, it should be pointed out that although autonomous, each case study must be also related to the main report so that specific findings that follow can be interpreted in the context of more general principles concerning efforts for implementation.

DESCRIPTION OF THE AREA

Yakima Valley contains a total area of 15,850 square kilometers (km) (6,120 sq. mi.) and occupies the south-central part of the State of Washington. About three-fourths of the Valley is in the Columbia Basin physiographic province, with the remainder in the Cascade Range. The Cascade Range generally bounds the Valley to the west, with the Wenatchee Mountains forming the northern boundary, and Rattlesnake Hills to the east and Horse Heaven Hills to the south separating the Valley from the Columbia Valley.

The Yakima River and its tributaries drain the Valley. The river heads near the crest of the Cascade Range northeast of Mount Rainier and flows for 216 miles in a generally southeasterly direction to its confluence with the Columbia River near Richland. It is the largest single river system located entirely within the State of Washington. Major tributaries include the

Naches, Cle Elum, Kachess, and Teenaway Rivers. The total annual flow leaving the Valley under natural conditions would be approximately 4,420 million cubic meters (3,580,000 acre-feet). The actual flow is 2,890 million cubic meters (2,340,000 acre-feet). The average annual irrigation diversions within the basin are 2,920 million cubic meters (2,365,000 acre-feet) of which 1,410 million cubic meters (1,140,000 acre-feet) are consumed and 120 million cubic meters (100,000 acre-feet) are diverted from the basin.

The climate varies from desert conditions in the lower Valley to a moist alpine type in the higher mountains. The irrigated area of the upper Valley receives from 250 to 380 millimeters (mm) (10 to 15 inches) of precipitation per year, while the lower Valley receives less than 250 mm (10 inches).

Agriculture is the primary economic activity in the Valley. The City of Yakima is a center for processing of both fruit and vegetable crops grown both in the Valley in adjacent valleys. The area is the largest producer of agricultural commodities in the State of Washington. The market value at the farm of all agricultural products sold in the Yakima Valley exceeds $200 million annually, or an average of $600 per acre. This is more than one-fifth of the on-farm value of all agricultural production in Washington. Moreover, Yakima County ranks first among counties in the Nation in the production of apples, hops and mint.

Population densities are high in the valleys and low in the surrounding rangelands. The present population is slightly in excess of the 1965 figure of 185,500 and is centered in a series of towns along the Yakima River.

DEVELOPMENT OF IRRIGATION

The first known attempt at irrigated agriculture in the Valley was made in 1853 at the Ahtanum Mission near Tampico (USDA, 1974). In 1867, farmers were diverting water from the Naches River and by 1870 there were 400 hectares (ha) (1,000 acres) under irrigation in the Yakima Valley. The early systems were privately constructed and served easily accessible lands along the main stem of the Yakima River and the lower portions of the major tributaries.

During 1886-88, the Northern Pacific Railroad's transcontinental line reached the area and extended over the Cascades to Puget Sound. As it had been granted a considerable land area in the Valley, the Railroad and other sources of private capital undertook large investments in irrigation in order to attract settlers. The Sunnyside Canal was started in 1890 to divert water from the Yakima River and by 1892 forty-two miles of canal were completed. In 1900 management was taken over by the Washington Irrigation Company. In the meantime, several other canals were constructed by private capital so that by 1900 the Yakima Valley was the most extensively irrigated area in Washington, with 27,000 ha (67,000 acres). This had expanded to 50,000 ha (125,000 acres) by 1905 when irrigation by the Bureau of Reclamation and the Office of Indian Affairs began.

The Yakima Valley is now one of the most extensively irrigated areas in the United States, having six storage dams, five diversion dams, two hydroelectric plants, six major governmental irrigation projects, plus numerous small private irrigation systems and districts. The total area served by irrigation facilities in the Valley is approximately 204,000 ha (505,000 acres), of which 168,000 ha (416,000 acres) are served by governmental projects. Water for the remaining irrigable land is supplied through Warren Act contracts and by individuals diverting from small streams. About 7,300 ha (18,000 acres) are irrigated by ground water.

Approximately 80 percent of the irrigated area of the Valley is watered by furrow or flood irrigation methods. The remainder is sprinkler irrigated except for a few hundred acres of trickle irrigation. There is currently a marked trend towards sprinkler systems.

The Water Quality Problem

With the advent of irrigation in the Valley, the quality of water in the Yakima River and its tributaries has declined. Some of the degradation is directly due to irrigation return flows, while further deterioration is associated with fruit processing plants and other agricultural and industrial enterprises attracted to the Valley by the existence of a strong irrigated agriculture base.

In the upper reaches of the Valley, water quality is virtually unimpaired. Although mineralization increases more than fourfold in going from the headwaters to the mouth, the water still remains in the low salinity class and is suitable for reuse as irrigation water. The main effect of irrigation activities is high concentrations of suspended sediment, phosphates and nitrates (Pacific Northwest River Basin Commission, 1971, Appendix XII).

Suspended solids in return flows settle and interfere with drain design flow capacity and cause wear of pumps and sprinklers. Where discharged to the river, they settle behind diversion structures and require periodic removal. Associated with the sediment is attached phosphate which frequently reaches levels in the lower river above the potential algal bloom limiting concentration. Similarly, nitrogen levels, which are a consequence of the percolation of irrigation water applied in excess of crop needs, greatly exceed the potential algal bloom limiting concentrations in the lower river. Heavy growths of plankton and higher forms of aquatic life are consequently found in the river from Wilson Creek, a few miles below Ellensburg, to the mouth. The photosynthesis and respirational activities of these organisms cause a wide diurnal fluctuation in several water quality parameters including dissolved oxygen, pH and alkalinity (CH2M/Hill, 1975).

Organization of the Report

The report is organized in a manner that both concentrates at key findings of the research and follows the general process developed by the interdisciplinary team for building the basis for implementing measures to improve irrigation return flow quality.

Section 2 summarizes the major findings and conclusions of the study, while Section 3 contains a series of recommendations concerning solutions and approaches per the problem in the Valley. Section 4, then, begins in detail the description of the physical, economic, legal, and social characteristics of Yakima Valley. Following the outlining of the area, Section 5 specifies the context within which the problem of irrigation return flow quality exists. The specific causes of this problem (again in terms of physical, economic and social parameters) are discussed in detail in Section 6. The two ensuing Sections, 7 and 8, identify first a wide range of potential solutions and, then, assess solutions against criteria of appropriateness, acceptability and feasibility.

SECTION 2

CONCLUSIONS

As stated in the main report, the control of water quality raises two basic issues, namely incentives and enforcement. At the same time, irrigation return flow is seen as a non-point source of pollution whose control has been ineffective due to the complexity surrounding this situation. In this regard, the present study concentrated on two major topics: first, in describing the parameters of the problem in the Valley; and, second, in explicating a process of assessing solutions leading towards implementation efforts.

As far as the causes of the problem are concerned, following a detailed description of the area, a series of causative factors were identified including inappropriate irrigation practices and methods; lack of appreciating the nature of the problem; lack of communication; inefficient water use; no internalization of pollution costs; constraints on water transfers; failure to enforce beneficial use provisions of law; and, a whole host of related conditions contributing to water quality problems of return flow.

The assessment process included the generation of a wide range of potential solutions; the evaluation of such solutions by the research team, water administrators and water users; and, the identification of technically, economically, legally, and socially feasible solutions. At the end of such an assessment process, the research team arrived at a series of both specific as well as overall findings regarding irrigation return flow quality control.

SPECIFIC FINDINGS (potential causes and solutions to the problem)

1. The irrigation methods used in many parts of the Valley are inappropriate in relation to the topography and soils. The high velocity furrow streams erode large quantities of sediment which are ultimately moved to the drainage ways and the river. The most effective controls would be provided by a change in irrigation methods (e.g., to sprinkler and trickle irrigation).

2. Overapplication of irrigation water results in excessive surface runoff and subsurface drainage, with consequent removal of sediment and adsorbed phosphates in the first case, and nitrates and other dissolved salts in the second case, to the river. Better utilization of the water could be achieved by improving existing irrigation methods and by providing a higher level of management.

3. The inappropriate use of fertilizer in conjunction with the overapplication of water has caused nitrate-nitrogen concentrations in the river

to increase to unacceptable levels. Improved fertilizer management practices are required to effect a change in the quantities, timing and placement of fertilizers.

4. Washington has made the transition to government jurisdiction over water resources allocation, distribution and administration by making the appropriation doctrine the exclusive system of water allocation for surface water in 1917 and ground waters in 1945.

5. Washington had adopted an integrated approach to water quantity and quality administration of the law in 1971. The Department of Ecology (DOE) has jurisdiction over both characteristics of water in the Office of Water Programs.

6. While the National Pollution Discharge and Elimination System (NPDES) program has been accepted, no regulations for permitting irrigation return flow have been adopted.

7. No state low-interest loan program is available to individual water users for water quality control improvements on the farm.

8. In the Yakima Valley, the water rights are held by the U.S. Bureau of Reclamation under various decrees with three irrigation districts, the primary distributors to water users.

9. Transfer of water within districts is constrained and not widely practiced between districts.

10. Irrigation districts under Washington law have been reluctant to assume responsibility for water quality as well as quantity control, but since the Water Resource Act of 1971, it may be strongly asserted since they have the responsibility.

11. The potential threat to the water supply from the reserved water doctrine on the adjacent Indian Reservation is real and causes great concern in the Valley.

12. The absence of economic markets to allocate irrigation water causes water to be underpriced.

13. The underpricing of water results in its excessive use relative to other inputs, such as labor and capital, and contributes to irrigation return flow pollution.

14. Moreover, farmers have an economic profit motive to avoid costs associated with controlling return flow pollution, thus contributing to the problem.

15. Creating an economic market for allocating irrigation water represents the first step in solving the problem.

16. Water pollution remaining after a market is created could be dealt with by extra-market mechanisms such as taxes and subsidies.

17. Perception and demonstration of the problem of return flow is vital for any efforts to implement the provisions of PL 92-500.

18. A common definition of intolerable degradation would be part of the effort of showing how present irrigation practices contribute to the problem.

19. There is a pervasive non-holistic thinking by farmers regarding water in the Valley and absence of regional identifications with a widespread belief that "others" are to blame for whatever problem may exist with regard to water quality.

20. Finally, there are non-effective linkages between farmers and administrators and lack of more active participation in district affairs.

OVERALL FINDINGS

In terms of more general findings and of integrative commentary, the following remarks underline the conclusions of the study:

1. Under the existing situation in the Yakima Valley, water users have no particular incentive for change (especially for voluntarily assuming water quality management) unless an explicit legal and/or economic incentive or disincentive mix can be established.

2. In this regard, the circumstances in the Valley point out that there are actually incentives for maintaining the same practices that contribute to pollution in the sense that the system works in such a fashion that it does not provide motivation for change. In many respects, the system imposes penalties for those who wish or are attempting change.

3. There seems to be an inability by many in the Valley to view the problem in a holistic fashion, as particularly pertinent, or as urgent and, thus, questions are raised as to the credibility of immediate attention and solutions to a not well-defined or accepted problem.

4. The presence of a pilot project in the area (Sulphur Creek) was unique in that it has increased awareness as to the problem, solutions and nature of irrigation return flow quality control. At the same time, the specific implementation approach recommended in this demonstration project has created questions and ambivalent feelings as to the pros and cons of the solutions advocated, particularly as to corrective measures vis-a-vis irrigation return flow. Overall, however, there has been an increased awareness as to the need to do something which, if nothing else, has brought about increased interagency cooperation.

5. In the case of Yakima, the State also has taken an active role, providing better coordination and involvement. This is derived from the positive attitude of DOE as well as from the fact that there seems to be a

public recognition by all appropriate authorites of the problem which ultimately enhances the potential tractability and solution of return flow problems.

6. Finally, the findings of this particular study and the analysis of material concerning the Yakima Valley confirm the general hypothesis of the study that there does exist a variety of appropriate technologies and technological measures. Throughout this study, as well as throughout the main report, the key problem remains the implementability of solutions, particularly through the acceptance of a combination of institutional mechanisms in the context of appropriate technological solutions.

SECTION 3

RECOMMENDATIONS

In view of the approach taken by the study and juxtaposition between describing potential solutions, arriving at appropriate solutions, and building the basis for acceptable solutions, recommendations also reflect the compatibility between appropriate and feasible strategies in implementation efforts. More specifically, the following recommendations expand the thrust of the study and supplement key provisions of the main report.

1. Studies should be undertaken to evaluate the downstream damages due to water pollution. Such studies would delineate the distributional impacts of benefits and costs from measures to improve irrigation return flow quality in order to develop more exact standards of cost-sharing. In essence, the share of the burden between the farmer and society should be more accurately evaluated in order to arrive at a better estimation of whether the farmer should pay the full cost, or the government should share the eventual cost.

2. Given the first recommendation, solutions to problems of irrigation return flow quality control should deal with causes and not symptoms. This means the tracking of the ultimate conditions that result to water degradation, especially through a careful analysis of the provisions of the legal system and the creation of a market and other institutional mechanisms that could reach the roots of the problem rather than the manifestations of it.

3. In terms of implementability, the most acceptable methods are those for which we have the most control. In this respect, inappropriate solutions are those that are superimposed on the system and are not part of the local control. Thus, local solutions are needed which maximize implementability and are sensitive to the problem at hand, and which may also require the creation of new institutions. In the case of the Yakima Valley, there is need for some new overall unit that would control irrigation in the Valley on a valley-wide basis. However, whenever possible, existing institutional bodies should be utilized rather than superimposing artificially conceived organizations.

4. There must be greater participation by the farmers and users in order to enhance the feeling of joint action, involvement and attitudes of democratic decision-making. This implies that the implementation efforts should be part of a community-wide effort and of a total involvement rather than part of handed-down or dictated solutions.

5. The demonstration project currently under operation in the Valley should be continued and expanded in order to incorporate all the technological solutions identified in the main text. At the same time, the tractability of

the problem would be enhanced by the introduction of such additional considerations as new irrigation methods, fertilizer management, irrigation management, etc. Thus, it is equally important to expand such demonstration projects in order to incorporate institutional "solutions" on a basin-wide basis and, therefore, attack the problem through a more holistic approach rather than only through technological measures. However, while the demonstration project should be on a basis that would be wide enough (perhaps a district or a region), it should not encompass such a wide territory as to lose its effectiveness as a demonstration project.

6. Washington appears to have a strong legislative basis for incorporating water quality as a specific element of a water right and should exercise this power on all new, transferred or extended rights.

7. An administrative decision should be tested to require a higher degree of public accountability by the irrigation districts in water quantity and quality management.

8. The Bureau of Reclamation, as holder of water rights for delivery of water under contract to the irrigation districts, should negotiate a revised contract which acknowledges degradation to water quality from agricultural water use, set out criteria for use, and provide mechanisms (legal, economic, physical) to facilitate improved use, i.e.:

   a. develop a basin water management plan that shows optimum use under quality/quantity conditions and needs;

   b. remove transfer restrictions between districts; and

   c. allow farmers to manipulate, trade or sell extra quantities of their water within the basin under delivery system constraints.

9. DOE should adopt criteria for beneficial use and expand their revolving fund program for water programs to include the water quality control objective.

10. Finally, it should be pointed out that as it happens with many other projects, solutions tend to be based on outside interventions quite often creating more complexity rather than simplifying the conditions of operation. It is recommended, therefore, that the approach towards implementation should be based on a determination of the ability of the farmer to solve the problem as well as of the capability of the government to promote irrigation return flow quality control. A balance must be reached between the ability of the farmer and the capability of the government in order to provide a mix of implementing measures that utilizes both motivational reinforcement (incentives) and administrative enforcement.

SECTION 4

CHARACTERISTICS OF THE STUDY AREA

PHYSICAL CHARACTERISTICS

Hydrologic Basin

The Yakima River system drains an area of approximately 16,850 kilometers (km) in central Washington (Figure 1), extending from the eastern slope of the Cascade Mountains through the lower plateau and bottom lands in a southeasterly direction to the Columbia River. In the headwaters area, three large glacial lakes--Keechelus, Kachess and Cle Elum--have been dammed to form storage reservoirs to augment the river flow in late summer. Additional dams have been constructed on other tributaries for the same purpose, as shown in Table 1.

TABLE 1. RESERVOIRS HAVING A TOTAL CAPACITY OF 5,000 ACRE-FEET OR MORE, YAKIMA VALLEY

Name	Stream	Total Storage (ac.-ft.)	Active Storage (ac.-ft.)	Area (acres)	Use[1]
Bumping Lake	Bumping River	33,700[2]	33,700	1,310	IR
Cle Elum Lake	Cle Elum River	436,900	436,900	4,800	IR
Clear Creek Lake	N.F. Tieton River	5,300	5,300	265	IR
Kachess Lake	Kachess River	239,000	239,000	4,525	IR
Keechelus Lake	Yakima River	157,800	157,800	2,526	IR
Rimrock Lake	Tieton River	198,000	198,000	2,528	IR
TOTALS		1,070,700	1,070,700	15,954	

[1] R=Recreation; I=Irrigation.

[2] English to metric conversion factor: 1 acre-foot = 1,234 cubic meters
1 acre = 0.4047 hectares.

SOURCE: Columbia-North Pacific Region Comprehensive Framework Study, 1970.

In its 350 km flow to the Columbia, the river traverses three structural basins having worn through two mountain ridges to form steep-walled canyons. The upper basin is largely forested with extensive irrigation development on the Valley floor. From the upper basin, the river flows through 40 km of

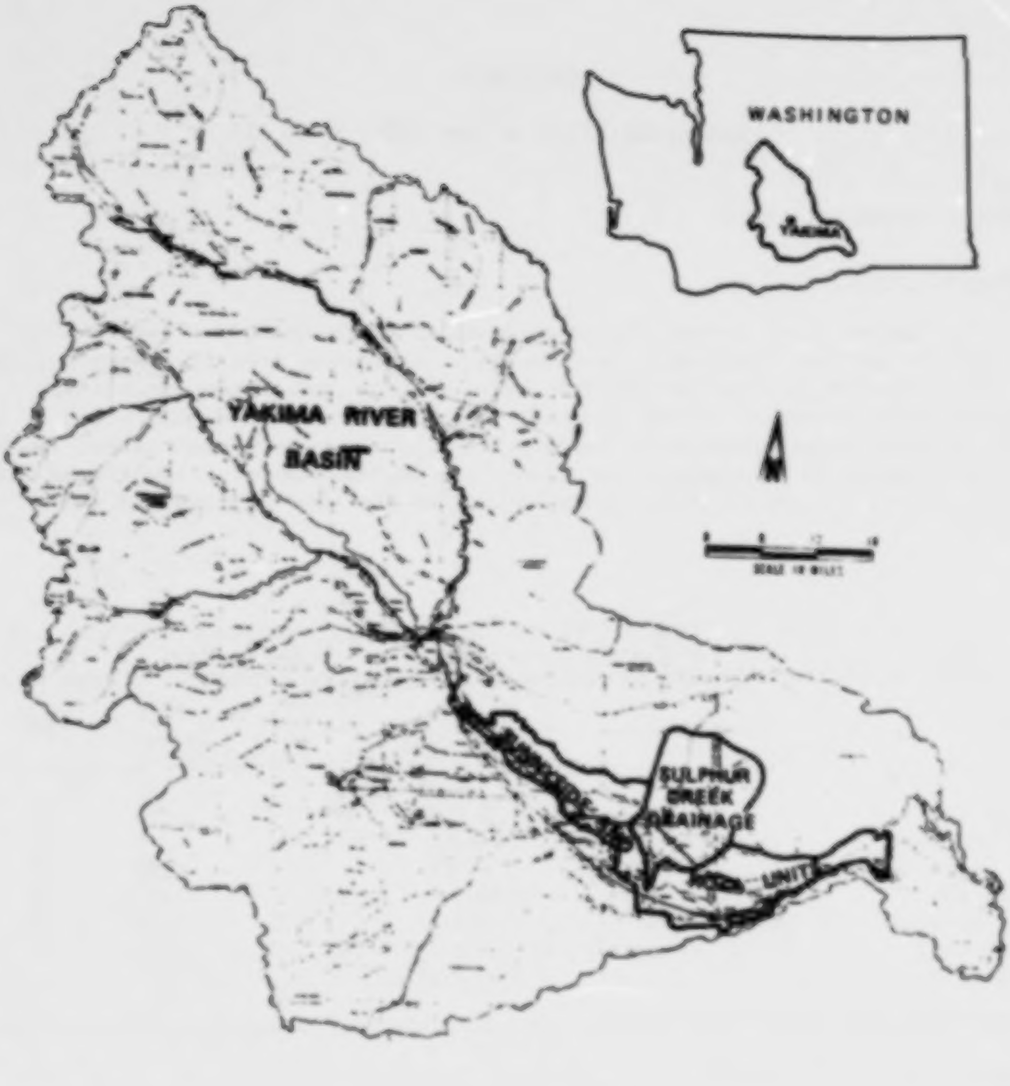

WASHINGTON
YAKIMA
YAKIMA RIVER BASIN
SULPHUR CREEK DRAINAGE
ROZA UNIT
SCALE IN MILES

Figure 1. The Yakima River system.

canyon into the middle basin, which contains a number of irrigation districts. In this middle basin, the Yakima River is joined by its principal tributary, the Naches River. Leaving the middle basin, the river passes through Union Gap and into the lower basin which is also extensively irrigated.

The principal tributaries to the Yakima River progressing downstream are the Kachess, Cle Elum, Teanaway, and Naches Rivers, plus the Swauk, Wilson, Manastash, Wenas, Ahtanum, Wide Hollow, Toppenish, and Satus Creeks. The Naches River is the largest tributary. The mean annual flow data for the main stream and major tributaries and drains are shown in Table 2.

Seven aquifer units have been delineated in the Yakima Valley on the State Geologic Map. The three most important are the alluvial deposits, the Ellensburg Formation and the basalt of the Columbia River Group. Moderate to moderately large yields can be obtained from wells in any one of the three units at favorable locations, and there has been considerable development and utilization of ground water from each. High yields are also available at many other locations. The other aquifer units have not been extensively tested. The chemical quality of the ground water is generally good to excellent for most uses (Pacific Northwest River Basin Commission, 1970, Appendix V).

Topography and Soils

Elevations within the Yakima Basin range from 2,408 meters (7,899 feet) at Mount Daniel in the Cascade Range, to 104 meters (340 feet) above sea level at the point of discharge to the Columbia River. The Valley bottoms, the adjoining terraces and the surrounding gentle slopes contain the basin's agricultural land. Irrigated lands range in elevation from a low of 120 meters (400 feet) in the Kennewick District to a high of 670 meters (2,200 feet) in the Kittitas District. In the higher regions of the north and west of the basin, the soils are chiefly shallow to deep and broken by outcrops of the underlying rock. The general landscape is dissected by canyons, ravines and stream courses and the relief for the most part is steep to very steep and unfavorable for cultivation.

During the glacial time, the canyons and deeper basins were flooded when the main river system was dammed. Thick deposits of silty to sandy sediments of glacial origin accumulated in the lake. After the dam broke and the streams were again free to cut their channels to former depths, much of the lake sediment was eroded. Remnants still remain throughout the area.

Since the disappearance of the lake, windblown materials have blanketed most of the area. Some of the material is of local origin, while other material has been transported from outside the subregion. Much of the soil, especially in the upland areas, has developed from the windblown mantle. This has left predominant soils of medium textured sandy loams and silty loams to considerable depth, usually underlain with gravel or decomposed basalt.

Climate

The climate of the basin is essentially continental in character, although tempered by the prevailing westerly winds from the Pacific Ocean.

TABLE 2. MEAN ANNUAL FLOW DATA FOR THE YAKIMA BASIN*

Main Stem Tributaries Canals	Drainage Area Sq. Mi.	MEAN MONTHLY FLOWS - Cubic Feet/Second												Annual Acre-Feet
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	
Yakima River near Martin	55	254	164	92	80	18	29	50	489	771	744	747	643	246,000
Kachess River near Easton	64	111	50	74	39	48	28	48	314	498	694	943	720	202,000
Kittitas Canal	--	(225)	0	0	0	0	0	(215)	(790)	(935)	(1,130)	(1,115)	(835)	(320,000)
Cle Elum River near Roslyn	203	401	260	197	64	89	59	257	1,696	2,382	2,269	2,295	1,401	686,000
Ungaged-1	173	240	344	507	418	398	498	1,025	1,241	650	235	156	170	372,000
Yakima River at Cle Elum	495	781	181	870	601	553	614	1,165	2,950	3,366	2,812	3,026	2,099	1,186,000
Teanaway River below Forks	172	65	125	160	265	360	475	620	1,110	530	130	35	30	235,000
Swauk Creek near Cle Elum	88	9	33	26	37	45	187	189	122	33	7	3	3	44,000
Naneum Creek near Ellensburg	70	17	22	23	23	34	38	85	198	144	45	24	19	41,000
Manastash Creek near Ellensburg	76	12	24	19	24	24	102	135	175	113	34	15	13	44,000
Ungaged-2	693	355	390	389	201	215	267	777	69	168	48	208	315	200,000
Yakima River at Umtanum	1,594	1,239	1,412	1,487	1,151	1,231	1,683	2,971	4,624	4,354	3,076	3,311	2,479	1,750,000
Roza Canal	--													
Bumping River near Nile	71	116	203	174	70	103	127	134	755	840	535	346	192	217,000
American River near Nile	79	77	136	160	117	121	145	350	740	661	303	92	58	179,000
Tieton River at Tieton Dam	187	221	178	176	144	167	58	87	764	1,170	1,200	1,150	872	358,000
Tieton, Wapatox, Selah Canals and City of Yakima		(343)	(303)	(366)	(343)	(410)	(480)	(452)	(797)	(968)	(977)	(982)	(906)	(445,000)
Ungaged-3	604	352	480	709	624	707	892	1,488	2,000	1,356	648	469	490	632,000
Naches River below Tieton River	941	423	667	853	612	688	742	1,607	3,462	3,064	1,709	1,075	706	941,000
Wapatox Powerhouse Return	--	300	320	370	340	370	450	370	400	430	470	470	450	285,000
Roza Powerhouse Return														
Ungaged-4	944													
Yakima River above Ahtanum Creek	3,479	1,799	2,184	2,996	2,930	3,599	3,723	5,315	7,304	6,746	3,976	3,212	2,731	2,830,000
Ahtanum Creek at Union Gap	173	23	31	45	86	133	138	130	212	184	37	18	23	64,000
Sunnyside Canal	--	(435)	0	0	0	0	(155)	(829)	(1,190)	(1,254)	(1,260)	(1,230)	(1,010)	(450,000)
Wapato Canal	--	(304)	(17)	(23)	(19)	(19)	(177)	(1,234)	(1,882)	(1,944)	(1,913)	(1,758)	(1,364)	(652,000)
Ungaged	8						NEGLIGIBLE							
Yakima River at Parker	3,660	1,083	2,198	3,018	2,997	3,713	3,529	3,382	4,444	3,732	840	424	380	1,791,000
Ungaged-5	1,699	691	529	20	75	303	101	365	1,525	1,920	1,014	1,065	1,435	504,000
Yakima River at Mabton	5,359	1,774	2,727	3,038	2,922	3,410	3,630	3,747	5,969	5,652	1,854	1,489	1,815	2,295,000
Chandler Canal	--													
Kennewick Canal	--	(96)	0	0	0	0	(34)	(182)	(262)	(276)	(277)	(271)	(222)	(99,000)
Ungaged-6	256	373	407	495	44	66	89	13	5	33	334	366	401	149,000
Yakima River at Kiona	5,615	2,051	3,134	3,533	2,966	3,344	3,685	3,552	5,712	5,409	1,911	1,584	1,994	2,345,000

Source: Ch2M, "Characterization of Present Water Quality Condition"(January 1974).

* From USGS Records for period 1908-1972, although few stations have complete records. Where records covering shorter periods were available, the long-term average was compiled from available records and correlated with adjacent stream flow records. In addition, some data on long-term flows were taken from the Columbia North-Pacific Region Comprehensive Framework Study.

Conversion Factor: 1 square mile = 2.590 sq. km.
1 cubic foot per second = 0.02832 cubic meters per second.
1 acre-foot = 1,234 cubic meters.

Differences in altitude result in a wide range of precipitation throughout the basin, averaging 2,780 millimeters (mm) annually at Snoqualmie Pass in the headwaters area and 183 mm annually at Yakima in the arid to semi-arid farming region. Normally, about three-quarters of the precipitation falls in the non-irrigation season.

Temperatures also vary according to elevation, averaging 5.5°C at Snoqualmie Pass in the upper basin to 10°C at Yakima in the lower irrigated valley. Minimum temperatures ranging from -25° to -35°C have been recorded, with minimums of -15° to -25°C recorded nearly every winter. Maximum temperatures are recorded a few times nearly every summer, with an extreme of 46°C recorded in the lower valley. The average frost-free period ranges from 106 days at Cle Elum to 174 days at Wapato. This long growing season and the high daily summer temperatures, abundant sunshine and long daylight favor rapid plant growth as long as moisture is supplied by irrigation.

The temporal distribution of average precipitation and temperature at Yakima and Ellensburg is shown in Figure 2. The distribution is similar throughout the irrigated area of the Valley.

ECONOMIC CHARACTERISTICS

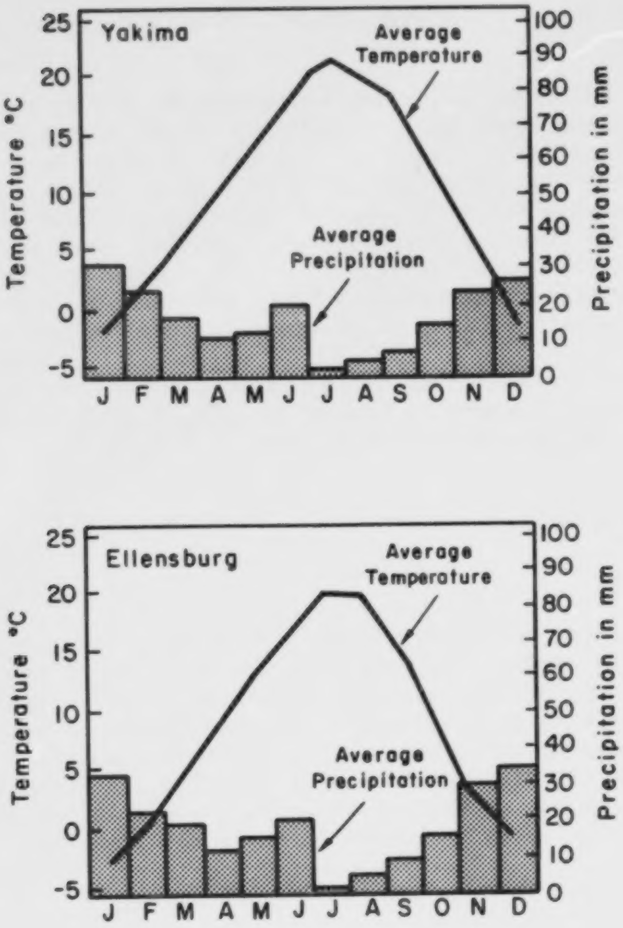
General Composition

The economy of the Yakima River Basin is largely based on the highly productive irrigated lands. The area's agriculture is varied, with a high proportion of acreage in fruit, vegetables and specialty crops such as hops and mint. There is a large development of agricultural marketing and processing industries based on these crops. The non-farm population of the area, however, is growing rapidly. Agriculture, forestry and fisheries were once the largest employers but in 1970 services became the largest, with trade ranking second and agriculture ranking third in total employment. Some segments of the agricultural industry are being mechanized, displacing many workers, while shortening the work season for others.

The seasonal nature of farm production leads to a pronounced fluctuation in the monthly employment rate with a peak occurring during the harvest months of October and November. Following harvest, as many as ten thousand persons are unemployed. Migrant workers and their families have historically filled these seasonal labor demands. More recently, many of the migrant families have established homes and live in the Yakima Valley all year. This development eventually adds to the local problem of unemployment as well as to the welfare load in the area. The median family income in the area is between $8,000 and $9,000 per year, yet the 1970 census shows that there were over 15,000 people earning less than $5,000 per year in the project area. (Washington Agricultural Experiment Station, 1972).

Agricultural Production

The Yakima River Basin continues to be the largest producer of agricultural commodities in the State of Washington. The market value at the farm



Conversion Factors -- °C = 5/9 °F -32
Temperature -- °F = 9/5 °C +32
Precipitation -- 1 inch = 24.5 mm

Figure 2. Average precipitation and temperature by months.

gate of all agricultural products sold in the Yakima River Basin is more than $180,000,000 annually. This is more than one-fifth of the on-farm value of all agricultural commodities produced in Washington in 1969. Yakima County ranks first among the counties of the nation in production of apples, hops and mint.

The farm sector of the Yakima Basin generates additional economic activity within local trade areas. It has been estimated that Yakima County has three job opportunities for each 25 acres of irrigated land. One of these jobs is on the farm, one in agricultural and service industries and another in government. Thus, the economic influence of agricultural production stretches beyond the local trade areas to many other parts of the State and Nation. A study by the Department of Agricultural Economics, Washington State University, found that for every $100 of sales at the farm gate in irrigated areas of Washington, half is spent for purchases from non-farm industries (Yakima-Kittitas Resource Conservation and Development Project, December 1974). Finally, some of the value added is retained by the farm family and hired workers and enters the economic stream as personal living expenditures.

Washington farmers sell most of their products to non-farm industries within the State. These industries process, store, finance, and market these products and thereby add to their value. According to the above study, farm sales of $180,000,000 will generate a value added of about $400,000,000 within the State of Washington before they are consumed or leave the State. Besides the fifty percent of their products sold within the State, Washington farmers also sell products valued at approximately $53,000,000 to foreign countries, $27,000,000 to the rest of the United States, and about $15,000,000 directly to consumers. Without any doubt, a vigorous economy characterizes the life of the region.

The Role of Irrigation

Although there are over 30,000 ha (75,000 acres) of dryland being farmed within the Yakima Valley, production of these acres is hardly significant. Irrigation water is the lifeblood which supports the great majority of the agricultural economy. Water is delivered to the farmers by one of the 25 irrigation districts within the Yakima Valley. The allotments to the individual farmers vary among the districts ranging from about 2,223 mm per hectare (3 acre-feet per acre) per year, to about 3,705 mm per hectare (5 acre-feet per acre). Although the method of water pricing varies somewhat within the Valley, most farmers receive water according to the total acreage to be irrigated. The charges for this allotment vary from $27.18 to $29.65 a hectare ($11 to $12 an acre), up to about $39.54 or $42.01 per hectare ($16 or $17 per acre) irrigated. In this respect, there is little incentive for an individual farmer to use any less than his full allotment. In the long run, such a situation produces a counterintuitive culture and hinders efficient allocation of precious resources.

SOCIAL CHARACTERISTICS

Human Ecology

The Yakima Valley is essentially rural in nature, although rapidly changing in more recent years. It incorporates the counties of Kittitas, Yakima and Benton. The general population characteristics show that the median years of educationare approximately 12.2 years; the unemployment rate is approximately 8 percent for men and 10 percent for women; the percentage of farmers or farm managers in the Valley runs from 2.1 percent in Benton to 5.8 percent in Yakima; the median income runs from $8,062 in Yakima to $10,656 in Benton; and the per capita income generally falls in the range of $2,553 in Yakima to $3,204 in Benton (for more detailed information, see additional tables in Appendix A). There is also some urban growth in the Valley with the number of rural non-farm residents also increasing. Finally, the majority of the farm land is owned by independent, family-size farm operations.

These are some of the basic critical parameters and the broad social context within which social interaction is taking place and where innovations as well as implementation efforts are to be introduced. In this context, a description of social characteristics entails those aspects of the total environment that are deemed important or crucial for possible implementation efforts of an innovative program aimed at improving irrigation return flow quality. As an approach, therefore, the search for critical variables includes forces of urbanization and patterns of growth in the Valley, followed by a critical look at three conditions within the Valley: 1) the composition of the rural farm and rural non-farm population; 2) the type of farm organization; and 3) a description of the farm operation. From such dimensions one can trace a better picture of the diverse social situations that produce the network of facilitating or constraining conditions in any implementation effort.

The urban population within the Valley ranges from 51.2 percent of the population in Yakima County to 65.8 percent in Benton County. There are no urbanized areas, i.e., a central city of 50,000 or more surrounded by a closely settled territory; but there exists a number of smaller cities and towns ranging from 45,588 (Yakima) to 2,841 (Wapato). The fastest growing areas in the Valley are Richland and Ellensburg. In the rural sector (towns of less than 2,500 people and the hinterland), approximately 88 percent of the people live in places with populations less than 1,000. Towns with populations of 1,000 to 2,500 for the most part are losing people. Generally, the growth rate of the Valley is small with Ellensburg being the exception. Overall, the Yakima Valley is supporting a fairly stable population, with three further conditions being key determinants to the quest of how innovations may be accepted or rejected or implementation efforts undertaken, namely: a) characteristics of the rural population; b) type of farm organization; and c) farm operation.

The first condition concerns the composition and characteristics of the rural non-farm and the rural farm populations. Rural farm is defined by the census as residents living on a place of ten acres (4.05 hectares) or more from which sales of farm products of the preceding calendar year amount to $50 or more, or a place less than ten acres (4.05 hectares) from which sales of farm products of the preceding calendar year amount to $250 or more. In short, this definition distinguishes a population who utilizes the farm land in a different manner.

This rural non-farm population has a slightly lower level of formal education than the rural farm population--12.03 and 12.33 years, respectively; it has a similar median income, but a significantly lower per capita income (see further, Appendix A). Benton County has the highest median income for both the rural farm and the rural non-farm people, but the lowest ranked county for the rural farm median income is Yakima, while it is Kittitas for the rural non-farm people. Added to this diversity is a mixture of increase, decrease and stability in the three counties of the Valley, and, therefore, an interesting mix of individuals who by the nature of their relationship to the land will perceive irrigation and irrigation-related problems differently.

A second condition in the social structure of the Valley relates to the type of farm organization (Appendix A). The most prevalent form of management of a farm unit is the independent or family-farm organization. This includes not only farm units themselves, but also the acreage under control. Partnerships are second in the number of units but corporate farms are second with regard to the acreage managed. Indeed, Yakima County has the largest concentration of corporate farms in the Valley.

Another aspect of the farm organization is the tenure system of the operator. Tenure of the operator has been defined by the census in three ways: 1) full owners--who operate only land they own; 2) part owners--who operate land they own and also land they rent from others; and 3) tenants--who operate land they rent from others, or work on shares for others. The greatest percentage of tenured operators are the full owners. However, with regard to acreage farmed, part owner operators constitute the more significant proportion (Appendix A). These people can be part-time farmers, farmers renting land from other retired or elderly farmers, or they may be managers of other farms. Therefore, any innovation or effort for change introduced into the Valley will have to take into consideration that there are a lot of part-time farmers with their practices and values in many respects different than other types of tenured operators.

Finally, a third condition that may affect implementation efforts or acceptability of proposed changes is the operation of the farm; i.e., the amount of irrigation utilized and the productivity of the farm.

A great majority of the farm units, approximately 83 percent, utilize irrigation to some extent. The majority of these units are less than 40.07 ha (100 acres) in size, with the largest number of farms falling into the category of 4.05 to 19.83 ha (10 to 49 acres) in Yakima and Benton Counties. Also, the total amount of acreage that is irrigated is disbursed throughout the various farm size units. For example, corporate farms do not control a large concentration of irrigated acreage, but farms of all sizes own significant amounts of irrigated land (Appendix A). This means that any innovation that is introduced into the area cannot concentrate on one specific type of farmer who irrigates.

In addition, the productivity of the farm unit is among the determining factors to the question of how any proposed change will be accepted. In each of the Valley's counties, the largest group of farmers are classified as part-time, i.e., those farm units that earn $50-$2,499 of farm product sales and are run by operators who are under 65 years of age and work off the farm 100 days or more in the census year (Appendix A). The next predominant category is that of the $2,500-$4,999 range in Benton and Yakima Counties (and in Kittitas the $20,000-$29,999 category). While the individual modal categories show that the concentration of farms is to be found in the lower or middle levels of productivity, the combination of the categories into the census' economic classes show that the distribution of farms is fairly evenly spread throughout the various economic categories. Again, the implication of the above is the degree of heterogeneity in the Valley and, therefore, which will be the recipient of any innovation.

In summary, the human ecological description of the Yakima Valley demonstrates that while the population in the Valley is fairly stable, there are a number of conditions which contribute to heterogeneity and, therefore, to a diversified approach vis-a-vis implementation efforts. There are significant differences in the type of residency in farm operation, and in the manner in which farms are operated. In addition, there is in process a turning-over of farms by the European origin owner/managers who live in the Wapato Indian Reservation to new Indian owner/managers. This action may induce further changes in the existing situation regarding irrigation quality and alter significantly the context within which implementation efforts must be considered.

Institutional Setting

Social institutions in their broadest definition are crystallized patterns of behavior. In the present discussion, the institutional framework that relates to irrigation return flow is made up of a number of organizations representing Federal, State and local levels of interest. Regarding this problem area, the critical organizations are the Bureau of Reclamation, the Soil Conservation Service (SCS), the Department of Ecology, and the Irrigation Districts (Figure 3).[1]

The Bureau of Reclamation performs the tasks of constructing irrigation and flood control works as well as all associated structures, such as bridges, roads, power lines; basin water management planning; and administration, operation and management of irrigation works constructed by the U.S. Government (CH2M/Hill). With regard to irrigation quality, there are questions as to the authority of the Bureau to confiscate water that is not being used for beneficial purposes. Officials in Yakima maintain that their hands are tied by contracts with the districts and that the Bureau cannot really tell the districts how to run their operations. Officials from the Department of Ecology state that the Bureau does have the authority for water management and therefore can establish and enforce some tough measures on irrigators in order to maintain the quality of the river. Finally, legal opinions with

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[1] While a summary of the specific organizations is introduced here, Section 4, "Legal Characteristics," discusses these organizations in detail.

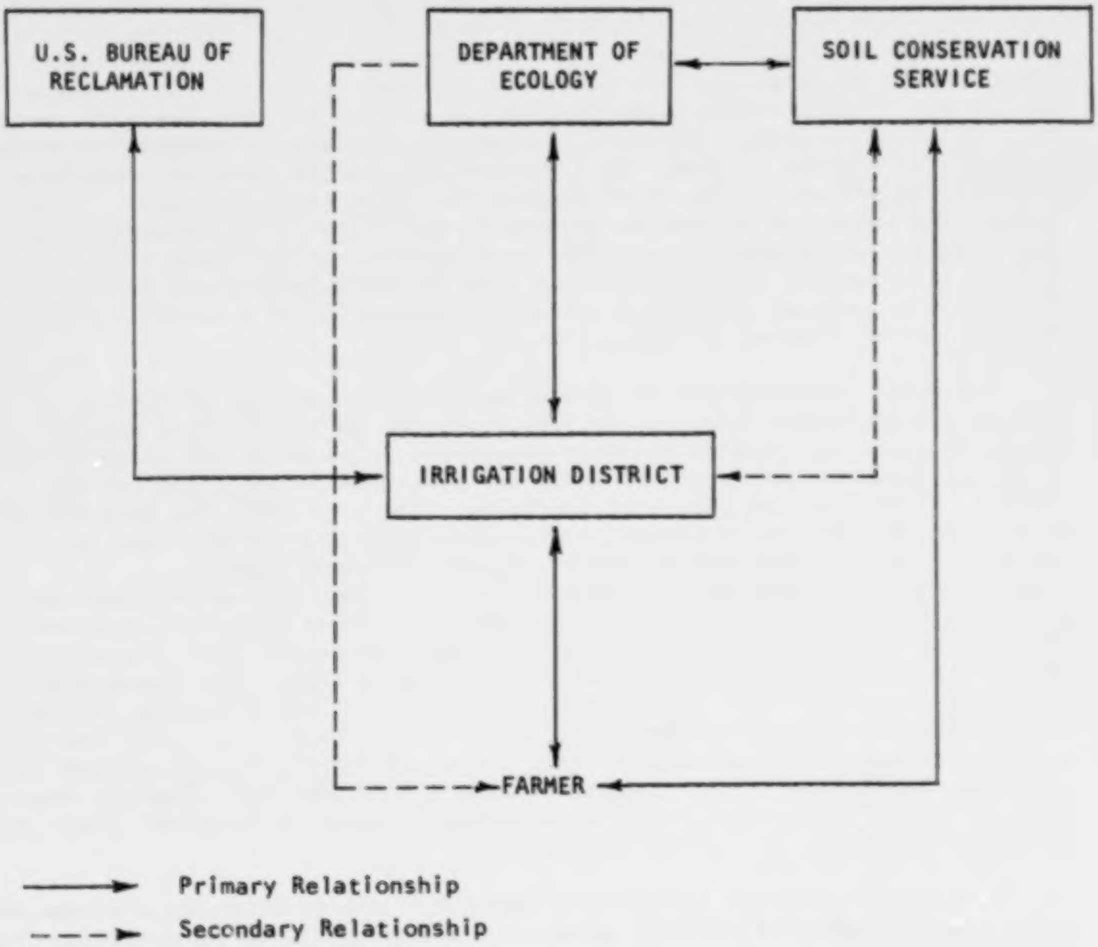

U.S. BUREAU OF RECLAMATION
DEPARTMENT OF ECOLOGY
SOIL CONSERVATION SERVICE
IRRIGATION DISTRICT
FARMER
Primary Relationship
Secondary Relationship

Figure 3. Critical organizations involved with irrigation return flow problems.

regard to beneficial use of the water have indicated that the Bureau does have the authority to confiscate the excess water that is not used beneficially. All in all, however, there is still a debate as to the course of action of the Bureau with regard to this central water quality management issue.

The Soil Conservation Service (SCS) was created to prevent erosion, protect rivers and harbors from the effects of erosion and to increase fertility of croplands (CH2M/Hill). Their main function with regard to water quality management is to establish farm plans for the most beneficial use of water. The SCS has no enforcement authority and the only incentives that this agency can provide is by grants and loans through the Agricultural Stabilization and Conservation Service program. This program has limited resources and therefore limited effects on the total program for water quality control. Essentially, SCS bases its success on voluntary compliance to its recommendations. Specifically, the agency is currently working with various farmers on a project to clean up the irrigation return flow in the Sulphur Creek area. This project is an unusual case where actual implementation of a specific water quality control program is taking place.

The Water Resources Act of 1971 directed the Department of Ecology to develop and implement a program to facilitate the decision-making process with regard to water and related resource management, allocation and use as well as to ensure that the waters of the State are protected and utilized for the greatest benefit of the people of the State. The core staff for this State Water Program consists of eleven people representing the disciplines of regional planning, resource economics, aquatic biology, water resource planning, sanitary engineering, hydraulic engineering, recreation resource planning, forest science, and civil engineering. There are other programs directly or indirectly related to the State Water Program, i.e., shoreline management, water rights, water monitoring, flood control, and sewage drainage basin planning. This comprehensive program is directed towards public participation involvement; coordination of Federal-State-local water resource planning and management activities; monitoring of Federal activities and regulations; development of alternative plans and programs; and, finally, evolvement of a system to evaluate the consequences of proposed programs, plans and policies--environmental, social and economic.

Some of the problems seen by the Department are a State-wide shortage of water, the problem of financing large-scale irrigation projects resulting from the decreasing financial role of the Federal government, and the conflict between increasing out-of-stream use for irrigation, hydropower production, etc., and the preserving of instream flow and quality for fish, wildlife, recreation, and aesthetics. Some of the recommendations put forward are to change and modify the State water code in order to allocate water on a term base which is subject to judgment of beneficial use by the State; increase State funding of some irrigation projects; and establish a new adjudication procedure of existing water rights.

In this general context, the thrust and emphasis of the Department are congruent with the broader rationale for its existence, namely, the water resources of the State. The Department is pursuing a water program along a direction that includes: 1) consolidation of basin water resource management programs (23 basins in the State); 2) establishment of a State-wide water resource management policy; and 3) creation of project/program position statements. Thus, basin management programs will provide major policy on future water allocation, including priorities between uses, quantity of water to be reserved for specified future uses, flows to be maintained in streams and rivers, and stream closure to further appropriation. State-wide policies demarcate critical problem and issue areas for an overall policy consistent with integrated resource management throughout the State. In this regard, the integrity of the State's water resource is also being represented by the Department through interstate commissions and by intergovernmental planning.

In view of the above, it is obvious that the Department of Ecology, with its state-wide interest in total water management, looks at irrigation return flow on a broader scale and on a more holistic basis. This agency sees the use of the Yakima River in a more comprehensive manner than do most of the water users and, therefore, its concern with return flow is of a different nature. The importance of this approach as well as working philosophy and value differences can be seen in the everyday workings of the Yakima division of the DOE with regard to citizens meetings, the cleavage between the DOE and the farmer, and its working relations with the Bureau of Reclamation. At the end, the implications for eventual implementation efforts become obvious in terms of conflicting approaches and hierarchy of goals to be achieved.

The final critical organization of the institutional framework in the Valley is the organization closest to the farmers, namely, the irrigation district. The irrigation district is an organization that is created by a group of water users for the purpose of supplying irrigation water to those users. The district is run by a board, consisting of elected farmer representatives, along with a manager or secretary. This district is obligated to deliver water to a user based on the contract between him and the district. A district charges the users a set fee for operation and maintenance of the district and for delivery of the water. With regard to water quality control, there are questions as to the authority of the district. The DOE maintains that the district does have the authority to control the quality of the runoff from the farm back to the district laterals; while the districts themselves insist that their authority over the water ends at the user's headgate.

The districts have formed two major associations: The Yakima River Basin Association of Irrigation Districts and the Sunnyside Board of Control. The Basin Association includes six major districts: Kennewick, Kittitas, Roza, Sunnyside Valley Irrigation District, Yakima Reservation, and Yakima Tieton. This association consists of the wealthiest and largest districts, all of whom have storage rights to the six reservoirs serving the USBR's Yakima Project. The Joint Board of Control is operated by the Sunnyside Valley Irrigation District for the management of the Sunnyside division of the Yakima Project. The Board also includes six other small irrigation districts. Major problems are solved with direct support from Sunnyside, while minor problems are solved by the smaller districts themselves. This arrangement allows the smaller districts to be administratively independent while still allowing them the ability to acquire the needed resources to maintain their operations.

The above points out that cross-cutting organizational arrangements, overlapping jurisdictions and debated lines of authority provide a complex background of institutional practices and decision-making apparatuses. It is within this institutional setting that various communication channels emerge, various decisions must be made and various strategies to implement those decisions are established. Together with a heterogeneous socio-demographic context, they affect the search for alternative strategies in implementing irrigation return flow quality control measures. Furthermore, the legal arrangements in the area accentuate further the complexity of identifying, assessing and implementing solutions appropriate to the physical and social conditions of the Valley.

LEGAL CHARACTERISTICS

Historical Water Law

Due to unusual climatic conditions which exist in Washington, its water laws have been adjusted to accommodate the continuing development of the State. Initially, the riparian doctrine was the basic law of the State, even though rights to water flowing through public lands could be acquired by diversion and use (Riparian and Appropriation Rights to the Use of Water in Washington, Horowitz, 7 Wash. L. Rev. 197, 1932). In 1917, Washington adopted the appropriation doctrine as the exclusive means of acquiring a right to use surplus surface waters of the State (Revised Code of Washington, Sec. 90.03.010), and in 1945 the appropriation doctrine was extended to ground waters of the State (R.C.W. 90.44.010 to 90.44.250).

Recent amendments to the water code have attempted to accomplish two major objectives. First, all aspects of water right administration and water quality control are vested in the Department of Ecology (R.C.W. 43.21A.020) to provide coordination and integration of water resources management. The creation of the Department of Ecology saw the abolishment of the Department of Water Resources, the Water Resources Advisory Council, the Water Pollution Control Commission, and the Air Pollution Control Board. All of the powers, duties and responsibilities of the above agencies are vested in the Department of Ecology (R.C.W. 43.21A.060 and 43.21A.300). Secondly, legislation was enacted to recognize and protect the public interest in preserving the environment, thereby assuring a fair balance between utilization and preservation of the State's water resources (R.C.W. 90.54.010 to 90.54.910; Sec. 43.21C.010 to 43.21C.900).

State Water Quality Law

Riparian Rights--

A riparian right arises by virtue of the ownership of land adjoining a stream and is an incident of the ownership of the abutting land (Hayward v. Mason, 54 Wash. 653, 104 P.141, 1909). Riparian rights, as against the State, do not exist because the State owns the bed of the stream (Proctor v. Sim, 134 Wash. 606, 236 P.114, 1925).

Although a riparian right is acquired as an incident to the purchase of riparian land (Benton v. Johncox, 17 Wash. 277, 39 P.485, 1897), it can be severed from the land and transferred independently or reserved by the grantor (Pleasant Valley Irr. and P. Co. v. Barker, 98 Wash. 459, 167 P.1092, 1917). Acquisition of a riparian right can also be accomplished under adverse possession (Smith v. Nechanicky, 123 Wash. 8, 211 P.880, 1923).

An appropriative right is a right to divert and make use of the water (Madison v. McNeal, 171 Wash. 669, 19 P.2d 97, 1933). It is a usufractuary right (Ibid.). The basis and the limit of the right acquired is that quantity of water which can be beneficially used (Miller v. Wheeler, 54 Wash. 429, 103 P.641, 1910). State law provides that appropriators who are first in time are first in right (R.C.W. 90.03.010). The right is only acquired by complying with statutory procedures.

Though both riparian and appropriative rights are recognized, they are subject to many of the same constraints. To begin with, beneficial use has been used to define the extent of appropriation and riparian rights, which divert and use water from a stream (Ibid., In re Stranger Creek, 77 Wash. 2d 649, 466 P.2d 508, 1970). This beneficial use limitation does not apply to riparian uses which do not remove water from the stream. These latter uses include boating, swimming and other recreational uses in the stream (R.C.W. 90.14.020).

Until 1967, prospective rights of the riparians were unclear. Earlier decisions indicated that riparian owners were to be protected to some degree when future use was the issue. The 1967 Water Right Claims Act cleared up this problem. That Act required that riparian uses be adjudicated along with appropriation rights and have a priority assigned to them. It also ended the possibility that a consumptive use could be established by means of riparian land ownership.

Appropriative Rights--

The appropriation system is the exclusive method of acquiring rights in unappropriated water as provided by the water code passed in 1917 (R.C.W. 90.03.010 to .480). In order to initiate a water right under the code, an application for a permit must be filed with the Director of the Department of Ecology (R.C.W. 90.03.250) containing information relevant to the applicant, source of water supply and use (R.C.W. 90.03.260). In order to approve such an application and issue a permit, the Director must find that there is unappropriated water in the source and the proposed use will not conflict with existing rights nor prove detrimental to the public interest (R.C.W. 90.03.290).

If the water is for irrigation purposes, the Director must also determine what lands are capable of irrigation from the proposed source; when the application does not provide sufficient information to make all findings necessary, the Director has the discretion of issuing a preliminary permit for no longer than three years and requiring the applicant to provide the prescribed surveys, study and other data (R.C.W. 90.03.250). The other option is to reject the application as incomplete and specify the deficiencies. This latter course causes the applicant to lose his priority date, however. If the permit is issued for irrigation purposes, the water right becomes appurtenant "only to such land as may be reclaimed thereby to the full extent of the soil for agricultural purposes" (Ibid.).

When the project works are completed, which must be with due diligence and within the time prescribed by the Director (R.C.W. 90.03.320), and the water is placed to beneficial use, a certificate is issued by the Director which evidences the perfected water right (R.C.W. 90.03.330). The priority date of the water right relates back to the date of the original application submitted to the Department of Ecology (R.C.W. 90.03.340).

The procedure for processing an application for a permit to use ground water is the same as the procedure governing surface waters (R.C.W. 90.44.060). Permits for ground water may not be granted beyond the capacity of a given water basin. This determination is to take into account a reasonable or feasible pumping rate in case of new developments in pumping or a reasonable or feasible reduction of pressure in the case of artesian developments. Permits also may not be approved if the Director determines that the new permit would impair an existing right (R.C.W. 90.44.070). Once the application is approved and the works are constructed, and the water is placed to beneficial use, the certificate evidencing the perfected right is issued by the Director (R.C.W. 90.44.080).

Beneficial Use--

Beneficial use is used to define the extent of an appropriation right in that an appropriation right can only be perfected for the amount of water which is beneficially used, and this is determined at the time the appropriation is made and completed. Thus, it is the quantity of water which is beneficially used that is the right acquired and not the amount of water which is diverted from the stream (R.C.W. 90.03.010, in re Stranger Creek, loc. cit.).

Adjudication of Rights--

Washington has a statutory procedure which provides for a comprehensive adjudication of rights among users of water from a common source. This procedure is initiated by a petition of one or more users from the source, which is filed with the Director of the Department of Ecology. Upon such a filing, the Director is to determine whether the interest of the public will be best served by such a determination. If he so determines, he prepares a statement of facts together with a map of the sources being investigated and files this information in the Superior Court of the county where the water source is situated. This statement is to contain the names of all known persons claiming a right from the source involved and a brief statement of facts leading to the necessity for such a determination (R.C.W. 90.03.010). Once the statement is filed, the summons is issued directing all water users to file a statement setting forth the nature and extent of the rights they claim (R.C.W. 90.03.120). If the owner of the water or the claimant of the water is unknown, service is made upon him by publication.

Once the service of summons is completed, testimony is taken by the Director relative to the claims of the individual users (R.C.W. 90.03.160). Upon completion of this task, a transcript of the testimony is prepared along with his report and all exhibits received in evidence. A time is then fixed by the court for the hearing on the Director's report and all users are notified at this time (R.C.W. 90.03.190). If no exceptions are filed by any interested party, the court enters a decree determining the rights according to the evidence and report of the Director. If exceptions are filed, the court may, at its descretion, take further evidence. The right of appeal from the district court decisions may be taken to the Supreme Court of Appeals (R.C.W. 90.03.200). On final determination of the rights by a court, the Director issues a certificate to each person entitled to the use of the water which describes the nature and extent of the water right awarded (R.C.W. 90.03.240). Failure of a person after proper legal service to appear and submit proof of his acclaim results in an estoppel barring him from asserting any right to the use of water from the source being adjudicated (R.C.W. 90.03.220).

In addition to the statutory procedure for determining rights to a water right source, a person aggrieved by any order or decision or determination of a Director or any water master may, after exhausting his administrative remedies, appeal the decision and have the matter reviewed by the superior court in the county where the use is situated. The appeal must be initiated, however, within twenty days of the order of the decision. The burden is on the user to prove the decision of the water master is prima facie correct.

Relinquishment--

Legislation was passed in 1967 providing for the relinquishment of water rights. The statute applies both to riparian and appropriation rights and to both surface and ground water (R.C.W. 90.14.130 to 90.14.210). The statute provides that any person is entitled to use water by virtue of an appropriation or is entitled to divert or withdraw water from a water course by virtue of the ownership of riparian lands, who voluntarily abandons or fails to use water without sufficient cause for five successive years after the date of act, 1967, relinquishes such right or the portion of the right not used. The water right thus relinquished reverts to the public and is available for appropriation (R.C.W. 90.14.160, 90.14.180 and 90.14.210).

The person whose right is threatened is to be notified by the Director of DOE to show why the right or a portion of it should not be declared relinquished (R.C.W. 90.14.130). The relevant statute provides a list of sufficient causes which will prevent a loss of the right in the case of nonuse. Such causes bridge the spectrum from drought to service in the armed forces to pendency of a suit or a claim on the right for future development (R.C.W. 90.14.140). Such a decision of the Director is subject to judicial review, but his decision in finding that a right has been relinquished is deemed by statute to be prima facie correct (R.C.W. 90.14.190). Thus the burden is on the user to prove the decision incorrect or arbitrary.

Abandonment of a water right requires an intent to voluntarily give up the right as well as non-use of the water. It could be used in a case where non-use of water has occurred and apparently the user intends to give up the right. Rather than let the water go to waste, the state or a private person by suit could attempt to declare the water right abandoned so as to establish the right to use it. Both the elements of a nonuse and intent, however, are necessary (Sander v. Bull, 76 Wash. 1, 235 P.489, 1913), and each case boils down essentially to a fact determination on its merits.

The Washington legislature has provided that no appropriative rights to the use of surface or ground water affecting either appropriated or unappropriated water may be acquired by prescriptive or adverse use (R.C.W. 90.14.220).

Condemnation--

Beneficial use of water is a public use of water in Washington. The result is that any person may exercise the power of eminent domain to condemn an inferior use for a superior use. The determination is left to the district court to decide which is of greater public benefit. The one exception to this is that no one may acquire irrigation water by condemnation since such an action could deprive a person of the quantity of water which would be necessary to fully irrigate lands using methods common to the area (R.C.W. 90.03.040). The point is of importance in that it appears that the statute does not require a user to use the best, most efficient or most productive irrigation method. This would appear to be a serious weakness in the Washington code.

Washington recognizes power production as being inferior to irrigation use if the water is to be solely used for power production. But, it recognizes also that domestic stock watering uses are superior to irrigation.

State Water Quality Laws

The responsibility for water quality control is also vested in the Department of Ecology (R.C.W. 43.21A.020 and 43.21A.060). To facilitate the accomplishment of this responsibility, the Director is authorized to promulgate rules and regulations pertaining to the statute of quality for the waters of the State (R.C.W. 90.48.035). The Act prohibits the discharge of any matter into the water of the State which will result in pollution (R.C.W. 90.48.080), and all plans and specifications for the construction of new sewer systems or the extention of existing sewer systems must be approved by the Director (R.C.W. 90.48.110).

Any person conducting a commercial or industrial operation which results in the disposal of waste into the waters of the State must obtain a permit for such a discharge (R.C.W. 90.48.160). This requirement extends to counties, municipalities, or public corporations operating domestic sewage treatment facilities (R.C.W. 90.48.162). Such permits must be initiated by formal application, and a provision is made for notice and public hearing before a permit request is acted upon (R.C.W. 90.48.170). The Director is to issue a permit unless he finds that the proposed discharge will pollute the waters of the State in violation of public policy (R.C.W. 90.48.180). The public policy of the State as defined by the Act is:

> To maintain the highest possible standards to insure the purity of all waters of the state consistent with public health and public enjoyment thereof; the propagation and protection of all wildlife, birds, game, fish, and other aquatic life; and the industrial development of the state, and to that end require the use of all known and reasonable methods by industries and others to prevent and control the pollution of waters of the state of Washington (R.C.W. 90.48.010).

Provision is made for modification of a permit if conditions change (R.C.W. 90.48.195). In addition, a permit may be terminated if it is determined that there was a misrepresentation in obtaining it, or a violation of the conditions in the permit, or a material change in the waste being disposed (R.C.W. 90.48.190).

In addition, there is authority for establishing water drainage basins and for adopting a comprehensive plan for the control and abatement of water pollution within such basins (R.C.W. 90.48.270). However, these plans cannot be adopted until there has been a public hearing on them. However, once adopted, they must be complied with (R.C.W. 90.48.280).

Persons aggrieved by the decision of the Director may appeal to the courts, and those person who violate the provision of the Act or any final order of the Director are liable to damages for injury or death of fish, animal or vegetation destroyed by their actions (R.C.W. 90.48.142).

Water Quality in a Water Right

Though the above provisions appear to show a concern for water quality in the State of Washington, there is a disappointing number of decisions dealing with the quality element of a water right--if indeed such an element exists.

As to the question of whether such a right exists, there is some difference of opinion among people in the water area in Washington. One individual flatly stated that there was no quality element to be found in a water right in Washington (Personal interview with Ralph Johnson, College of Law, University of Washington, Seattle, Washington, March 20, 1975). In his opinion, the debris cases were no authority for improving a water quality element.

On the other hand, another individual (Personal interview with Charles Roe, Senior Assistant Attorney General, State of Washington, Dept. of Ecology, Olympia, Washington, March 25, 1975) was equally sure that a quality element existed in Washington as part of a water right. To buttress this opinion, a case was cited which dealt with a complaint by a group of irrigators (Natches and Cowyche Ditch Co. v. Weikel, 87 Wash.). This case is concerned with siltation of irrigation works. The Washington Supreme Court refused to grant relief to the group because the pollution complained of did not interfere with the existing use. The interference was non-point in the sense that the siltation could not be traced to a single identifiable area. However, the Court was careful to point out that interference with a water right by pollution was a matter to be decided on a case-by-case basis. We thus conclude that a quality element does exist in Washington as part of a water right.

Administrative Regulations

The general administrative supervision of Washington's water resources is vested in the Department of Ecology. The general responsibility of the Department, according to the statute is:

> To establish a single state agency with the authority to manage and develop our air and water resources in an orderly, efficient

and effective manner, and to carry out a coordinated program of pollution control involving these and related land sources (R.C.W. 43.21A.020).

This Department is to develop and implement a comprehensive State water resources program (R.C.W. 90.54.040). It has the power to carry out the policies of the Department including reserving water and setting it aside for future beneficial use, or withdrawing it from appropriation while data is developed for sound decision-making (R.C.W. 90.54.050).

The administrative head of the Department is the Director, who is appointed by the Governor (R.C.W. 43.21A.050). An Ecological Commission was created to advise the Director on matters relating to: 1) the position taken by the State before any interstate body or agency on matters affecting the quality of the environment of the State; 2) the development of the State policies with regard to any comprehensive environmental quality plan; 3) procedures for considering and granting variances; 4) propose legislation relating to the Department; and 5) any other matter related to the Department and requested by the Director (R.C.W. 43.21A.190). As has been noted, with respect to initiation of new water rights, an application to appropriate must be filed and approved by the Director (R.C.W. 90.03.010 to 90.03.480).

To aid in the distribution of water according to water rights, the Director may appoint state employees who are responsible to the Director (R.C.W. 90.03.060). In order to facilitate this task, the Director may designate water districts and may adjust the boundaries of each district from time to time as conditions dictate (R.C.W. 90.03.360). The primary responsibility of the water master is to divide a water supply among the users according to their respective rights and priorities and to prevent a use of water in excess of the amount to which a user is legally entitled (R.C.W. 90.03.070).

Water users are required to install and maintain adequate measuring devices and control facilities (R.C.W. 90.03.360). It is unlawful to interfere with the regulation of these works, or with storage or water carriage facilities (R.C.W. 90.03.360).

Federal Law

The Yakima project, as with most of the congressional reclamation projects, was approved under the general authority of the Reclamation Act of 1902 (32 Stat. 388, 43 USCS 372). This statute: 1) established a reclamation fund created from receipts gathered from the sale of public land in the sixteen western states; 2) authorized the Secretary of the Interior to use this fund to investigate the possibilities of irrigation works and to construct those works; 3) withdrew those lands from public entry that are needed for irrigation works or that can be served by such works; 4) established the 160-acre limitation for single ownership; and 5) gave the Secretary of the Interior authority to acquire any property needed to carry out the Act, either by purchase or condemnation under judicial process (Id., as cited in Land Development and Water Use, Yakima River Basin, Washington, Appendix 6A, p. 1; Washington Agricultural Experiment Station, Pullman, Washington, 1972).

The irrigation works permitted and provided for under this Act had a split ownership. That is, the irrigation works were to pass to the owners of the land irrigated, but the title and management and operations of the reservoirs and the works necessary for the protection of these reservoirs remained in the government until Congress provided otherwise. This provision for Congressional or Federal Government control was due to the concern of an interference with state laws. Section 8 of the Reclamation Act of 1902 provides:

> ...that nothing in this act shall be construed as effecting or intended to effect or to, in any way, interfere with the laws of any state or territory relating to the control, appropriation, use or distribution of waters used in irrigation, or any vested right acquired thereunder. And the Secretary of the Interior, in carrying out the provisions of this act, shall proceed in conformity with such laws, and nothing herein shall in any way effect any right of any state or the federal government, or of any landowner, appropriator, or user of water, into or from any interstate stream or water thereof, provided the right to the use of water acquired under the provisions of this act shall be appurtenant to the land irrigated and beneficial use shall be the basis, the measure and the limit of the right (32 Stat. 388, 43 USCA 372 (8)).

The State of Washington enacted a statute in 1905 to give the United States authority to acquire property for the purpose of developing irrigated lands under the Reclamation Act of 1902 (R.C.W. Chapter 90.40 et. seq.). By this statute, the United States was granted the power of eminent domain to acquire the use of a right to any water or lands or property for the construction or maintenance or control of any project used for irrigation purposes regardless of who owned the property (R.C.W. 90.40.010).

Duties Under Repayment Contracts--

The contracts for repayment between the district and the United States define obligations of the parties regarding the operation and maintenance of the storage and conveyance systems as well as the allocation of water to the district and lands within the district along with a manner of assessment and repayment of the construction costs. The basic provisions of the contracts appear to be similar. They cover essentially the disposition of the return flows; what uses may be made of the water, and where it may be used; the conditions which would permit a change in district boundaries; allocation of water to lands within the district along with a recital of the obligations of the district to provide service to the members; and methods of rationing in times of shortage.

Return Flows--

The usual provisions in the contracts for the districts in the Yakima system provide that the United States retains ownership of the waste, seepage and return flow waters resulting from the irrigation of project lands. It is also provided that the United States or the district may use these waters which result from irrigation of lands within the district as a part of the supply to lands within the district and such supply shall be toward fulfilling the total supply to which the district is entitled under contract.

Authorized Uses and Place of Use--

There is generally a provision limiting the type of use to irrigation of lands which are classified as "irrigable" lands within the boundaries of the district. The contract terms usually limit the place of use to the lands classified "irrigable," and this is defined very narrowly. For example, the district is limited to a maximum of 72,000 irrigable acres, and water may be delivered only to lands which have been classified as irrigable with the approval of the Secretary of the Interior (Personal interview with Henry Vancik, Sunnyside, Washington, Rosa Irrigation District, March 24, 1975). There are, however, occasions when a contract provides for an expandable area of use under the conditions that the amount of water delivered to the district is more than can be beneficially used by the irrigable lands in order that the water provided can be used most efficiently (see Land Development and Water Use, Yakima River Basin, Washington, Appendix 6B).

Allocation of Water to Users Within a District--

Generally, the district water supply seems to be made available to users on a uniform basic allotment, usually three acre-feet per irrigable acre, with an additional provision that additional water may be purchased on an unlimited basis for some multiple of the basic charge. There are exceptions to this general outline: some of the districts' board of directors are empowered to determine the amount of water to be delivered to each acre, contingent upon payment of the basic charge, while some directors are empowered to set minimum quantities of water available to land, but are limited to the maximum amount which may be delivered there without charging an additional rate for any excess water. Still others allocate water on the basis of ownership of shares in the district, which represent shares in the water supply.

No matter what the method of allocation, the board of directors is under an obligation to operate their system (irrigation) with the goal of making available to each irrigable acre in the district the quantity of water to which it is entitled. This is subject to the option of refusing to deliver water to parties who fail to pay their share of operation and maintenance or construction repayment assessments.

The 1945 Consent Decree

On January 31, 1945, the United States District Court of the Eastern District of Washington, Southern Division, allotted the waters of the Yakima River among most of the irrigation districts in the basin (this material may be found in the "1945 Consent Decree" but this discussion of that decree relies heavily on a short synopsis found in Land Development and Water Use, Yakima River Basin, Washington, Appendix 6A, p. 4, 1972). The decree affirmed, basically, the allocation of water provided for in repayment contracts previously executed between the United States and water users. There were some differences, however, which necessitated mandatory contracts with some of the districts.

The decree basically tells the United States what obligations it has to deliver water to the parties affected by the decree. It does this by providing a schedule of deliveries and sets the basis for rationing water during times of short supply, which depends upon distinguishing between "total water supply available" and "natural rights." Total water supply available is defined as that amount of water available in any year from the natural flow of the Yakima River and its tributaries along with storage in the various government reservoirs in the Yakima watershed and from any other source. This is the amount available to meet the contract obligations of the United States to deliver water and to supply water rights claimed to the use of water on the Yakima River.

If the United States is not able to satisfy its obligations of the decree for any reason, such as drought, then each claimant is entitled to a pro-rate share of his claim. This share is calculated by looking at each claimant's entitlement as compared to the total of water supply available. This proportion is minus certain amounts which were listed in the decree as exempt from prorationing. These exempted amounts were natural flow rights which preceded development of storage by the United States, and which were established to the natural flow of the river prior to 1902. After withdrawals of water for a project, the United States may make a formal appropriation for a water right according to state law. The duty of the United States is to make, maintain and perfect the appropriation. It is allowed to assign such appropriation in the same manner as an individual.

Transfer of Water Within Irrigation Districts

There are several laws bearing on changes in types of use, places of use, or transfers of ownership. These are the Federal reclamation laws, state laws governing individual water rights and the powers of irrigation districts and repayment contracts between the United States and irrigation districts. There are constraints on transfers of water within the boundaries of an irrigation district, whether these transfers are between uses or users or places of use within that district. These constraints are: state law, repayment contracts the district might have with the United States, and bylaws and regulations of the district board of directors. Since an irrigation district is a creature of the State, it follows that it has those powers which have been conferred on it by statute or by necessary implications as a result of powers granted by statute (R.C.W. Title 87; see also, in re Riverside Irrigation District, 129 Wash. 627, 225 P.636, 1924). The powers granted by statute to the districts include: the power to construct or purchase works for the irrigation of lands within the district; the power to construct, acquire, operate and maintain a system for the sale or lease of water to the owners of irrigated lands in the district for domestic purposes; and the power to construct, operate and maintain a system of drains (R.C.W. 87.03.115 and 87.03.010).

These are general powers that do not provide much guidance when attempting to ascertain the extent of the power to apportion water and to subsequently transfer water within irrigation boundaries. Any powers the board of directors have to apportion water are to be exercised according to established bylaws, rules and regulations for the equitable distribution of water to the lands within the district based upon beneficial use requirements.

The phrase "beneficial use" is not susceptible to an easy definition. However, statute (R.C.W. 90.03.040) provides that all persons shall be provided that quantity of water which is reasonably necessary for the irrigation of his land, and that this irrigation is to be accomplished by the most economical method of artificial irrigation, which would apply to the land in question, according to the usual methods of artificial irrigation employed in the vicinity where the land is situated. In all cases, the court is the determining body as to what is the most economical method of irrigation (Id.). From this definition, it would appear that beneficial use means simply that amount of water sufficient to meet all crop requirements plus any reasonable losses in conveyance and application.

What the term "equitable distribution" means is not clear at all. It is assumed it means all landowners within a project area or within a district must be treated equally. If this is so, then it would follow that each landowner is entitled to the full supply of water needed to irrigate the crop which he is growing. This formula runs into difficulty in times of shortage, for it is then incumbent upon the irrigation district to determine if equitable distribution is the measure to proportionally reduce the allotment to the landowner. However, since the definition of beneficial use seems to include such elements as the type of crop growing on a certain type of land, then the proportionate reduction is going to have to take into account the types of crops involved and where they are being grown. Clearly, the administrative problem here becomes a severe one. The duties of the board of directors are further complicated by statutory directives that they distribute and apportion water of the district in accordance with the acts of Congress along with the rules and regulations of the Secretary of the Interior until full payment has been made to the United States for the project involved (R.C.W. 87.03.115).

There is some latitude and variation in the contract requirements and this is reflected in the district bylaws. One district which has been studied--the Roza Irrigation District--begins with a basic allocation of 914 mm (3 acre-feet) per irrigable acre as a basic allotment regardless of land quality. The water user is assessed a cost per acre for construction as well as cost per acre for operation and maintenance costs which include a small percentage for a reserve fund. Upon payment of his assessments, a water user is entitled to the basic 3 acre-feet allotment on demand within limits of the system's capacity. He may also purchase excess water at an increased price if such demand is within the limits of the system's capacity and if there is an adequate supply. In cases where demands exceed the delivery capacity of a system, all demands are reduced on a proportionate scale. This reduction is imposed whether the demand is for water within the basic allotment or for excess water.

In order to transfer a right, there are several restrictions. After payment has been made for the basic allotment in the Roza District, the first 3 acre-feet per acre may be transferred by the owner to another point of delivery provided the acreage to which the water is transferred is farmed in fact by the transferer as the bona fide owner or the leasee of that land for the year in which the transfer is to be effective. Also, written instructions are to be filed with the district and approved by the manager or the secretary. The water rights themselves cannot be transferred (Id., p. 13).

The effect of these regulations is that a water user is free to distribute his total supply around his acreage as he needs it in whatever manner he sees fit. But he cannot sell any portion of his supply to another water user.

The practices followed in the Roza District are substantially different from those practiced and reported in the Sunnyside Valley Irrigation District (Id., p. 14). The allocation of water for the Sunnyside District is made upon the basis of beneficial use. Beneficial use is defined by the district as the amount an individual needs to grow a crop. This amount is limited by the total supply available, the rights of other users and system capacity. This allocation system takes into account various soil types because the soil types vary from an excellent loam to a sandier soil as the land is found farther away and upslope from the river.

Maintenance in the Sunnyside District is done on a very local basis within the district itself. The district has divided itself into what are called Maintenance Districts which are landowner organizations on particular laterals with a district manager recording and levying assessments for each of these maintenance districts. The creation of these maintenance districts was necessitated by farmer inactivity. The first arrangement at Sunnyside was that farmers on laterals with less than 10 cubic feet per second (cfs) flow would get together on a certain day and clean out and repair the lateral. This became unsatisfactory as the individuals dropped out and the users at the end of the lateral found themselves doing all the work. This was combined with new owners coming in and refusing to do their share of the work. Consequently, the maintenance district was necessitated along with an enforcement of assessments to insure that these laterals are maintained (Id., p. 15).

The particularly lengthy discussion of the legal characteristics of the water resource in Yakima (and for that matter in many other western valleys) epitomizes the concrete difficulties of developing appropriate solutions in a combination of technological options and institutional measures.

Using, then, not only the limitations that the legal imperatives provide but also the physical, economic and social characteristics of the area, we should now proceed in describing the nature and causes of the problem of irrigation return flow and the articulation of potential solutions that would provide the basis for a strategy of implementing "packages" or combinations of solutions aimed at improving water quality.

SECTION 5

NATURE OF THE PROBLEM

This section attempts to relate the nature and characteristics of the problem of water degradation from irrigation at Yakima Valley. Central emphasis is given to the delineation of water quality standards and to the sources of water quality degradation. In the juxtaposition between the last two, the section concludes with an overview of future quality considerations.

WATER QUALITY STANDARDS

Water quality standards for the State of Washington were published by the Department of Ecology on July 19, 1973. These standards went into effect on July 19, 1973, and were amended effective August 20, 1973. The waters in the Yakima River Basin were classified into one of the five categories (AA, A, B, C, or Lake), depending upon quality or the desirable quality. Those listed as Class AA are:

American River from confluence with Bumping Lake to headwaters;
Bumping River from confluence with Naches River to headwaters;
Cle Elum River from confluence with Yakima River to Cle Elum Lake;
Naches River from Snoqualmie National Forest boundary to headwaters;
Tieton River from confluence with Naches River to headwaters;
Yakima River from Cle Elum River to headwaters.

Characteristic uses of Class AA fresh waters include, but are not limited to, the following:

- water supply (domestic, industrial, agricultural);
- wildlife habitat, stock watering;
- general recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating);
- fish reproduction, rearing and harvest.

Listed as Class A is:

Yakima River from Sunnyside Dam to Wilson Creek, with the provision of special conditions indicating that temperature of water shall not exceed 70°F.

Characteristic uses of Class A waters are the same as for Class AA waters.

Listed as Class B is:

Yakima River from confluence with Columbia River to Sunnyside Dam.

Characteristic uses of Class B fresh waters shall include, but are not limited to, the following:

- industrial and agricultural water supply;
- fishery and wildlife habitat;
- general recreation and aesthetic enjoyment (picnicking, hiking, fishing, and boating);
- stock watering.

Any water body not specifically listed is designated as Class A.

The water quality criteria for these classes are shown in Table 3. Frequent review of the uses and criteria are anticipated by the Department of Ecology and revisions will be undertaken as additional information is developed.

These classifications do not establish standards for concentrations of total dissolved solids, nitrogen or phosphorus levels or suspended solids, although the last may be associated with turbidity. Maximum desirable total dissolved solids concentrations depend on the use of the water and the presence of other constituents, but in any case are not a significant factor in the Yakima Valley. The presence of nitrogen and phosphorus is important in respect to algal growth, which may be indirectly indicated by dissolved oxygen levels and turbidity. For nitrogen (NO_3 + NO_2), the potential algal bloom limiting concentration is 0.30 mg/l. For total phosphorus and dissolved orthophosphate, the potential algal bloom limiting concentrations are 0.05 and 0.1 mg/l, respectively (EPA, 1975).

EXISTING WATER QUALITY

Sources of pollution in the Yakima Valley are closely related to the economic base of agriculture. Municipalities and industries are the largest sources of organic wastes. The food processing industry accounts for most of the industrial waste production and nearly three-fourths of the waste load is discharged to municipal systems. Diversion of water for irrigation tends to reduce the assimilative capacity of the river and return flows significantly affect water quality. Extensive stock watering and feedlot activities also have affected water quality.

The headwaters of the Yakima River and most tributaries are of adequate water quality for most purposes. However, during the period of low streamflow, the lower reaches of the river suffer from various water quality degradations. The most significant problems are high stream temperatures, heavy algal growths and bacterial contamination (Pacific Northwest River Basin Commission, App. 12). The present water quality for average flow conditions at a number of stations in the Yakima Valley is shown in Table 4.

TABLE 3. WATER QUALITY STANDARDS, STATE OF WASHINGTON.

Parameter	Class AA (Extraordinary)	Class A (Excellent)	Class B (Good)
Total coliform organisms (colonies/100 ml)	Median $\leq$ 50, with $<$ 10% $>$ 230*	Median $\leq$ 240, with $<$ 20% $>$ 1000*	Median $\leq$ 1,000 with $<$ 10% $>$ 2400*
Dissolved oxygen, mg/l	$>$ 9.5	$>$ 8.0	$>$ 6.5 or 70% saturation
Total dissolved gas	$\leq$ 110% saturation	$\leq$ 110% saturation	$\leq$ 110% saturation
Temperature $^{\circ}$C **	$\leq$ 15.6 (60°F)	$\leq$ 18.3 (65°F)	$\leq$ 21.1 (70°F)
pH	6.5 to 8.5, induced variation $<$ 0.1	6.5 to 8.5, induced variation $<$ 0.25	6.5 to 8.5, induced variation $<$ 0.5
Turbidity, JTU	$\leq$ 5 above natural	$\leq$ 5 above natural	$\leq$ 10 above natural
Toxic, radioactive or deleterious material concentrations	Below those affecting public health, natural aquatic environment or desirability of water for any use	Below those of public health significance, causing acute or chronic toxic conditions to aquatic biota, or adversely affecting any water use	Same as Class A, except related to characteristic water uses
Aesthetic values	Not impaired by presence of unnatural materials	Not impaired by presence of unnatural materials	Not reduced by unnatural materials which could affect water use or taint flesh of edible species

* When associated with any fecal source.

** t = permitted temperature increase; T = water temperature due to all causes combined.

TABLE 4. YAKIMA RIVER WATER QUALITY AT SELECTED STATIONS FOR AVERAGE FLOW CONDITIONS

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
						YAKIMA RIVER AT CLE ELUM						
Maximum Temperature (° C)	12.0	6.5	3.0	1.5	2.5	3.5	4.5	7.0	12.0	14.0	16.5	16.0
Dissolved Oxygen (mg/l)	11.6	12.0	12.2	12.3	13.0	12.1	11.7	11.3	10.4	9.4	9.4	9.5
Specific Conductance (Micro-mhos/cm)	55	57	57	56	66	61	58	52	49	46	44	48
Total Coliform (Colonies/100 ml)	36	430	155	67	476	101	23	100	106	330	85	280
Nitrate Nitrogen (mg/l) (N)	0.04	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.03
Orthophosphate Phosphorus (mg/l) P	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01
Turbidity (JTU)	1	1	1	2	1	1	1	1	1	1	1	1
						YAKIMA RIVER AT ROZA DAM						
Maximum Temperature (°C)	11.0	6.5	3.5	2.0	3.0	6.5	8.0	11.0	15.5	16.0	16.0	15.0
Dissolved Oxygen (mg/l)	9.8	10.2	10.6	11.8	11.4	12.6	11.2	10.0	8.7	9.2	9.5	10.5
Specific Conductance (Micro-mhos/cm)	142	141	126	119	125	140	101	109	108	85	89	108
Total Coliform (Colonies/100 ml)	220	400	2,900	7,900	3,500	2,000	1,175	850	900	750	700	1,600
Nitrate Nitrogen (mg/l) (N)	0.14	0.18	0.21	0.18	0.16	0.21	0.13	0.14	0.12	0.10	0.10	0.12
Orthophosphate Phosphorus (mg/l) P	0.04	0.06	0.08	0.06	0.09	0.10	0.10	0.06	0.04	0.04	0.04	0.05
Turbidity (JTU)	1	1	1	1	2	2	2	2	2	2	2	1
						LOWER NACHES RIVER						
Maximum Temperature (°C)	10.0	5.5	3.0	1.0	4.0	6.0	8.5	10.0	12.0	18.0	19.0	16.0
Dissolved Oxygen (mg/l)	11.6	12.2	12.9	13.2	12.9	12.9	11.0	11.2	10.4	917	10.1	10.4
Specific Conductance (Micro-mhos/cm)	92	86	73	77	75	86	85	62	57	65	68	76
Total Coliform (Colonies/100 ml)	95	85	50	175	132	54	200	260	570	405	608	850
Nitrate Nitrogen (mg/l) (N)	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.05
Orthophosphate Phosphorus (mg/l) P	0.02	0.01	0.01	0.03	0.02	0.04	0.02	0.04	0.02	0.06	0.05	0.06
Turbidity (JTU)	1	2	2	2	2	2	5	2	1	1	1	1

(continued)

TABLE 4 (continued)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
						YAKIMA RIVER NEAR PARKER						
Maximum Temperature (°C)	11.0	6.5	2.0	2.0	4.5	6.0	8.5	11.0	15.0	18.0	18.0	16.5
Dissolved Oxygen (mg/l)	9.8	11.0	11.0	10.8	11.7	11.7	11.7	10.7	10.2	9.1	9.3	8.5
Specific Conductance (Micro-mhos/cm)	183	178	144	128	130	137	103	89	81	103	112	130
Total Coliform (Colonies/100 ml)	1,100	850	2,500	3,500	2,100	1,300	3,300	2,400	1,300	3,000	2,400	9,600
Nitrate Nitrogen (mg/l (N)	0.24	0.22	0.20	0.22	0.20	0.31	0.11	0.13	0.10	0.10	0.13	0.18
Orthophosphate Phosphorus (mg/l) P	0.09	0.06	0.07	0.06	0.07	0.09	0.06	0.06	0.06	0.06	0.06	0.06
Turbidity (JTU)	5	3	2	15	8	9	20	20	5	5	3	4
						YAKIMA RIVER AT KIONA						
Maximum Temperature (°C)	12.0	7.5	4.0	3.0	5.0	7.5	10.5	15.0	18.5	22.0	21.0	16.0
Dissolved Oxygen (mg/l)	10.7	10.0	11.4	12.0	11.8	11.8	10.5	9.2	8.5	7.7	7.9	9.1
Specific Conductance (Micro-mhos/cm)	350	265	230	245	200	215	180	175	170	310	335	335
Total Coliform (Colonies/100 ml)	11,000	7,000	30,000	28,000	60,000	45,000	21,000	9,000	11,000	7,000	63,000	63,000
Nitrate Nitrogen (mg/l) (N)	0.85	0.82	0.85	0.67	0.73	0.73	0.40	0.62	0.53	0.78	0.89	0.98
Orthophosphate Phosphorus (mg/l) P	0.12	0.12	0.12	0.10	0.11	0.13	0.11	0.11	0.10	0.10	0.13	0.13
Turbidity (JTU)	3	3	3	15	15	15	15	20	10	10	6	5

SOURCE: CH2M/Hill, Characteristics of Present Water Quality Conditions (January 1974).

The comparison of existing river water quality shown in Table 4 to the water quality standards outlined in Table 3 indicates that in the upper reaches of the river the quality generally complies with the standards except for total coliform and occasionally temperature and dissolved oxygen levels. Additional data from the same source not included indicates that violations of these parameters are more common on the upper reaches of tributaries to the main stem of the Yakima River and less common on the upper reaches of tributaries to the Naches River. At Roza Dam, temperature and dissolved oxygen standards are generally violated during the summer months and the total coliform count during most of the year. In addition, nitrate-nitrogen levels show a marked increase and the threshold level for potential algal bloom is reached by orthophosphate. Data published by Sylvester and Seabloom (1963) for 1956-60 indicated that temperatures, nitrate and phosphorus levels were above acceptable levels as far upstream as Roza Dam. This was true for nitrates and phosphates even during the non-irrigation season.

At Kiona in the lower river, the standard for total coliform count is greatly exceeded year round. The potential algal bloom limiting concentration is exceeded for nitrates and orthophosphates year round, also. The temperature standard is occasionally violated.

The chemical, physical and biological quality of irrigation return flows in the Valley have been the subject of numerous past and on-going studies. Data obtained in these studies show that turbidity, BOD, dissolved solids, coliform organisms, and temperature are somewhat higher in irrigation drains than in the river. Pesticides and other agricultural chemicals have also been found in the drains (Pacific Northwest River Basin Commission, App 12). The average values of quality parameters for the major drains in the Valley for 1974 irrigation season are shown in Table 5.

As the return flow drains are not listed in the State water quality standards, they fall under Class A. The data in Table 5 indicates that drain waters markedly violate coliform standards and exceed threshold limits for nitrogen and phosphorus. A valuable comparison can be made between Tables 4 and 5 generally pointing out the differences in water quality of the river at various locations to the water quality in the drains. For example, orthophosphate levels during the irrigation season generally average about 0.05 mg/l in the river near the diversions, while during the 1974 irrigation season they averaged 0.15 mg/l in Sulphur Creek. Although nitrate levels cannot be directly compared, a similar trend can be noted.

Little data on ground water quality in the Yakima Basin exists. The available data indicates that the water is of good quality in the deeper aquifers and poorer in the shallow aquifers. Undoubtedly the shallow aquifers are affected more by salts and minerals leached through the soils by excess irrigation waters. An estimate of general ground water quality in the basin is given in Table 6 (CH2M/Hill, 1974).

TABLE 5. COMPARISON OF MAJOR DRAINS IN YAKIMA BASIN--AVERAGE VALUES FOR 1974 IRRIGATION SEASON

Measures Parameters	Sulphur Creek at Green Valley Rd.	Granger Drain at Highway 223	Spring Creek at Hess Rd.	Snipes Creek at Old Inland Empire Rd.	Wilson Creek at Canyon Road	Wide Hollow Creek at Washington Avenue	Moxee Drain at Birchfield Road	South Dr. at Highway 22 Near Satus	Marion Drain at Highway 97
Flow (cfs)	310	28	34	40	135	24	32	89	244
Temperature (^{o}C)	13	15.2	16.5	16.8	13.0	14.6	16.8	14.9	13.3
Dissolved Oxygen (mg/l)	10.0	6.8	8.1	8.0	8.3	8.2	7.4	8.2	8.8
pH (units)	7.6	7.7	7.8	7.8	7.8	8.0	7.7	7.8	7.6
Conductivity (Micro. mhos/cm)	261	404	299	193	230	288	372	412	281
Bacteria									
Total Coliform (Count/100 ml)	35,000	40,000	1,700	3,200	6,500	1,800	---	---	---
Fecal Coliform (Count/100 ml)	2,800	1,600	660	260	770	180	---	---	---
COD (mg/l)	13	22	14	10	14	14	17	15	10
Nitrogen -N									
$KO_3 + NO_2$ (mg/l)	1.80	1.64	1.23	0.25	0.38	0.65	0.81	1.88	2.30
Kjeldahl (mg/l)	0.59	0.80	0.40	0.29	0.42	0.52	0.60	0.61	0.42
Phosphate -P									
Ortho-P (mg/l)	0.15	0.18	0.08	0.03	0.09	0.09	0.18	0.10	0.08
Total P (mg/l)	0.45	0.54	0.25	0.18	0.15	0.12	0.40	0.22	0.13
Suspended Solids (mg/l)	229	157	87	84	20	13	134	48	20
Turbidity (JTU)	73	42	32	27	7	3	30	17	8

TABLE 6. GROUND WATER QUALITY IN THE YAKIMA BASIN

	pH	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	SO_4 mg/l	Cl mg/l	NO_3 mg/l	PO_4 mg/l	Hardness ($CaCO_3$)
Kittitas Valley	7.5	150	18	9	9	2.0	120	1.3	2.0	0.8	0.25	83
Sunnyside-Roza												
Shallow	7.9	295	48	14	17	7.4	190	44	11	2.3	0.07	180
Deep	7.8	240	15	6	45	10	210	2	9	0.2	0.08	65
Wapato-Satus												
Shallow	--	140	22	7.9	6.8	1.9	113	5.1	2.7	2.0	--	80
Deep	7.7	160	19	2.2	19	4.1	105	0.3	1.0	0.2	--	40
Ahtanum-Moxee												
Shallow	7.3	215	28	13	14	5	150	16	15	3.0	--	130
Deep	7.9	130	12	6.0	12	3.1	105	2.5	1.6	0.2	--	55

SOURCE: CH2M/Hill, 1974. Characterization of Present Water Quality Conditions, Yakima Basin Water Quality Management Plan (Draft) (January 1974).

SOURCES OF WATER QUALITY DEGRADATION

As related above, municipalities and industries are the largest source of organic wastes in the Valley. Agricultural drainage from the animal population is also a major pollution source. Other sources of pollution include wastes from the rural-domestic population, land use, recreation, and natural sources (Pacific Northwest River Basin Commission, App 12). However, according to Sylvester and Seabloom (1963), "Irrigation return flows were the major factor influencing the overall water quality of the Yakima River as compared with domestic sewage and industrial waste discharges."

Irrigation return flows comprise approximately 5 percent of the yearly Yakima River flows in the reach from Wilson Creek, a few miles below Ellensburg, to Sunnyside Dam. Below Sunnyside Dam this increases to over 30 percent. In the summer months, irrigation return flows constitute about 80 percent of the lower river (DOE, 1974b). The quality of water in the return flow drains has already been shown in Table 5 above.

The relative contribution of nutrients from agriculture (not including feedlots, drains and runoff from pasture land) in different subbasins of the Valley compared to other nutrient sources is shown in Table 7. About two-thirds of the total nitrogen present in the water at Kiona is added by irrigation return flows (DOE, 1974b). Except for natural loads, agriculture is also the most important source of phosphorus. The relative contribution of irrigation to flow, total dissolved solids, nitrogen, and phosphorus is shown in Figure 4 for different locations in the river. Nitrogen and phosphorus levels in the river increase with distance from the source and are markedly affected by the inflow from drains. A plot of nitrate and orthophosphate levels versus distance from the river mouth is shown in Figure 5. The marked increase in nitrate and orthophosphate levels below Sulphur Creek wasteway is particularly noticeable, as is the sharp increase in the nitrate level in the river at Granger.

Nitrate-nitrogen levels in the lower Yakima River have increased six-fold in the last twenty years (CH2M/Hill, 1975), and are mainly attributed to the accelerated use of fertilizer for crop production. Phosphorus levels are associated with high suspended sediment concentrations, as phosphates tend to attach to soil particles. Data presented by CH2M/Hill (1975) indicates that about 35 kilograms of nitrogen per hectare are discharged from Sulphur Creek alone each year, and in some areas the loss of phosphate could amount to over 45 kilograms per hectare each year.

Erosion of top soil from irrigated fields has been a problem in the Yakima Valley for many years. In 1937, the Soil Conservation Service measure irrigation furrow flow and soil losses from potato lands near Ellensburg and reported (in an unpublished document) that 20 to 75 percent of the water applied was lost as waste water with soil losses ranging from 70 to 135 tons per hectare (Hagan, *et al.*, 1967). In addition, as shown in Table 8 croplands in the Yakima Valley contribute 27 percent of the sediment yield while comprising only 18 percent of the area.

TABLE 7. NUTRIENT LOADS IN THE YAKIMA BASIN

Subbasin	SOURCE Natural	 Municipal	 Agriculture	 Septic Tanks	 Other*	 Total
			(tons per year)			
Nitrogen Load						
Upper Yakima	400	10	0	0	0	410
Kittitas Valley	220	60	170	3	240	693
Upper Naches	170	0	0	0	0	170
Middle Yakima	130	230	210	20	20	610
Lower Yakima	50	100	2,800	30	Unknown	2,980
TOTAL	970	400	3,180	53	260	4,863
Percent of Total	20%	8%	66%	1%	5%	100%
Phosphorus Load						
Upper Yakima	32	3	0	0	0	35
Kittitas Valley	130	17	15	3	0	165
Upper Naches	150	0	0	0	0	150
Middle Yakima	150	65	18	20	80	333
Lower Yakima	40	28	105	30	45	248
TOTAL	502	113	138	53	125	931
Percent of Total	54%	12%	15%	6%	13%	100%

* Residual from mass balance calculations, and includes feedlots, dairies, urban runoff, and runoff from grazing land.

SOURCE: Stansbury, M. and R. T. Milhous, 1975. Water Quality Aspects of Irrigation.

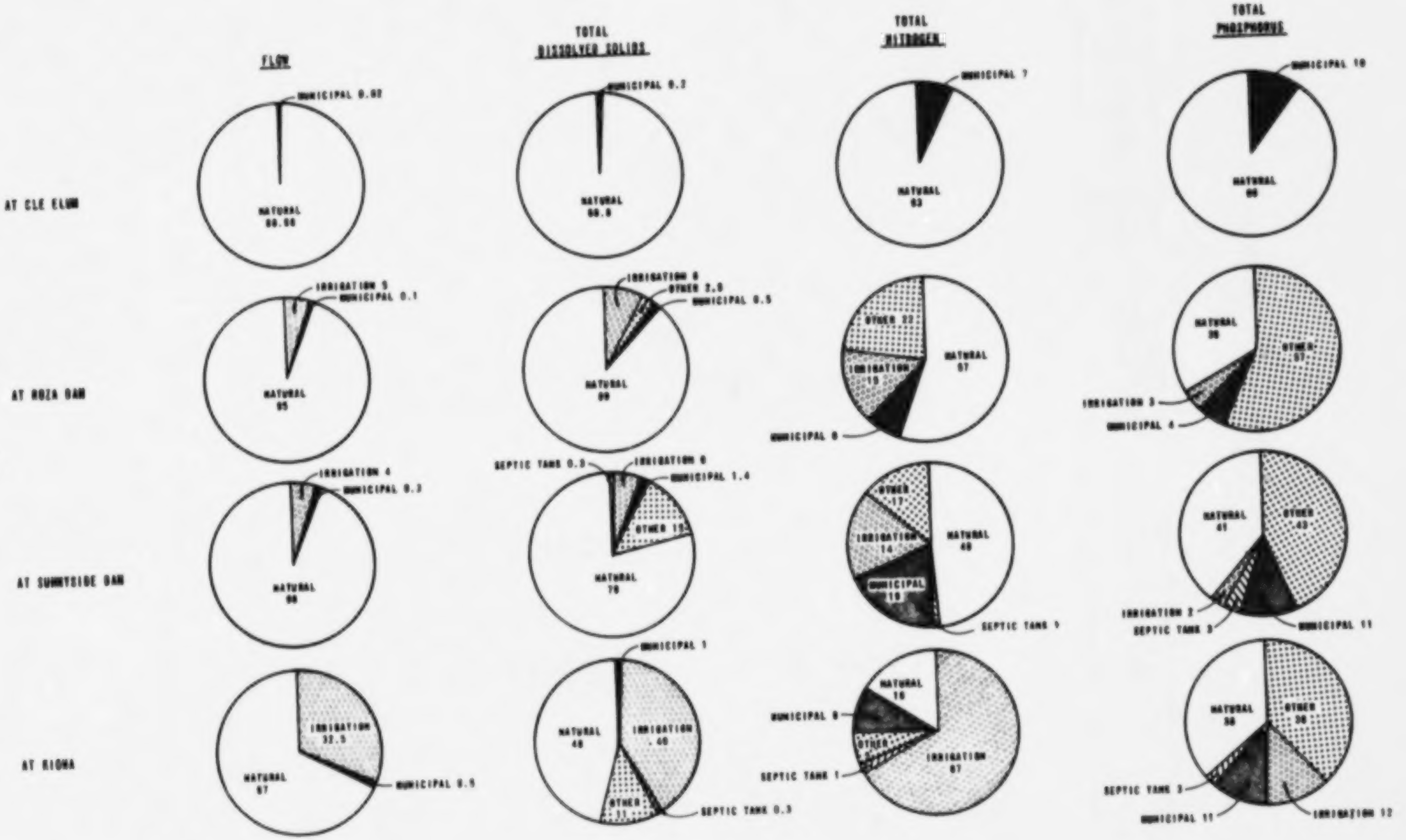


Figure 4. Sources of pollutants in the Yakima River: Values in percent--values for late August.

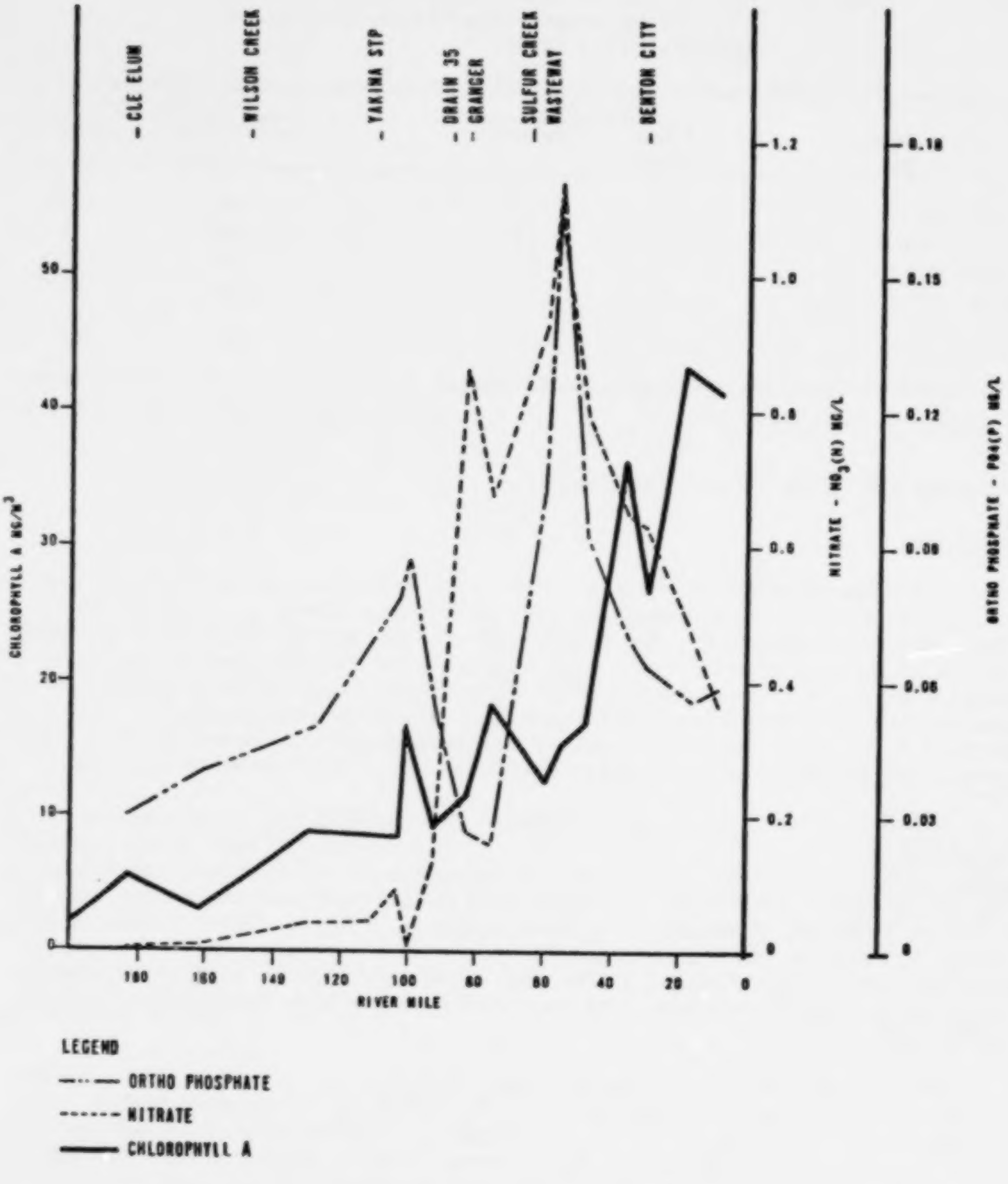


Figure 5. Variations in nitrate, orthophosphate and chlorophyll A in the Yakima River in August 1973.

TABLE 8. GENERALIZED SEDIMENT YIELD BY COVER AND LAND USE (Pacific Northwest River Basin Commission, Appendix VIII, 1971).

Cover and Land Use	Land Area		Sediment Yield	
	1,000 Acres	Percent	Ac-Ft/Year	Percent
Cropland	686.3	18	141	27
Forest Land	1,508.9	39	202	39
Range Land	1,534.8	40	158	30
Other Land	121.4	3	21	4
TOTAL	3,851.4	100	522	100

1 acre = 0.4047 hectares. 1 acre-foot = 1,234 cubic meters.

PROBLEMS DUE TO EXISTING WATER QUALITY

Nutrients

The concentration of the plant nutrients (nitrates and soluble phosphate) in the river is not high enough to have an adverse effect on crops or soils when used for irrigation. The harmful effects relate to the resulting stimulation of aquatic plant growth. Heavy growths of plankton and higher forms of aquatic plants are found in the river from Wilson Creek to the mouth. The photosynthesis and respirational activities of the organisms cause a wide diurnal fluctuation in several water quality parameters, including dissolved oxygen, pH and alkalinity (Pacific Northwest River Basin Commission, 1972).

The uptake of nitrogen and phosphorus by algae in the river was shown graphically in an earlier Figure (5). The data are averages of all samples taken at each location. Chlorophyll A is a measure of the amount of algae in the water body. The figure indicates that as nitrogen and phosphorus concentrations increase, Chlorophyll A also increases. In the lower reaches of the river, below mile 55, the chlorophyll continues to increase while the nutrients decrease. This indicates that the algae continues to utilize nutrients after major inputs decrease. The last major return flow is at about mile 60 (USDA, 1974).

As nitrogen and phosphorus are taken up by algae, the plants may remain in the system as bottom deposits or may be contained in floating mosses and, consequently, not measured in the water samples. Hence, nutrient concentrations could be higher than recorded. These floating mosses are aesthetically objectionable as well as requiring constant cleaning from screens at irrigation canal intakes. As they die off in late summer, they reduce the dissolved oxygen content, causing a deterioration of the fish habitat. The combination of lower dissolved oxygen content and other development-related effects has caused the present anadromous fish runs to decline to only four percent of their pre-1890 levels (Bell and Mar, 1974). Prior to the settlement of the Yakima Valley, the river was one of the most important fish producers in the Columbia River system.

Sediment

According to Carlile (1972), sediment pollution has become an ever-worsening problem in downstream diversion canals and in the Yakima River itself. Canal water receiving irrigation return flows often carries such a heavy sediment load that untreated water is unsuitable for irrigation. Some farmers have constructed desilting basins in an attempt to remove enough of the particulate matter to render the water fit for use. However, only a portion of the sediment can be removed and the remainder still causes serious problems in pumps, sprinkler heads and pipes. It is indeed ironic that, because of sediment pollution and the associated problems, many farmers are reluctant to convert from furrow to sprinkler irrigation. At the same time, total conversion to sprinkler irrigation would be a major step toward alleviating sediment pollution.

Economic consequences of sediment pollution are now being felt by cities and counties throughout the Yakima Valley. Benton County, located in the lower region of the Valley, spends upwards of $50,000 per year to remove sediment from road ditches and bridge approaches. City residents are faced with the task of replacing sprinkler heads and flushing pipelines day after day when using irrigation water to keep lawns green and gardens blooming. Pumps have to be torn down and cleaned and city officials are faced with the never-ending task of hauling silt from flush points in the city irrigation system. Coupled with impaired recreational and aesthetic values, public reaction against sediment pollution in the Yakima Valley has reached the point where interim measures are needed to combat the existing problem until improved water and land management practices can be implemented (Carlile, 1972).

In addition to the costs of sediment removal mentioned by Carlile above, $65,000 per year is spent in removing sediment from drains in the Sulphur Creek drainage and $50,000 per year in the Yakima-Tieton Irrigation District. Cost figures from other districts are unavailable.

The amount of sediment reaching the drains is only a small fraction of the total soil movement on the farm. The end of the irrigation furrow is the point where both runoff and soil loss are less than anywhere else along the furrow (Mech and Smith, 1967). Hence, the true economic consequences of sediment loss are difficult to gauge, as they must include the loss in productivity on the individual farms and the extra cost of fertilizer to compensate for nutrients lost.

FUTURE WATER QUALITY CONSIDERATIONS

About 205,000 hectares are presently irrigated in the Yakima Valley, with an average annual diversion of 1,500 millimeters per hectare. According to the Columbia-North Pacific Region Comprehensive Framework Study (Pacific Northwest River Basin Commission, App 12, 1971), irrigated acreage is projected to increase to 223,000 hectares by 1980, 231,000 hectares by 2000 and 247,000 hectares by 2020, the last being an increase of over 40,000 hectares from the present. However, an economic evaluation of potential irrigation development by the Washington State University Agricultural Research Center (1972) indicates that only 15,000 hectares hold high promise for future irrigation development and that this land would be irrigated with water from the Columbia River.

Irrespective of which projected figure is ultimately substantiated, careful consideration of future irrigation developments will be required to evaluate the impact on overall water quality. There is a potential for detrimental effects from increases in silt, fertilizers, pesticides, salt, and temperature in the return flow water. In addition, there is a potential problem of ground water buildup and of associated problems.

Water supply for any future development must be accomplished without reducing minimum stream flows. If the diversion rate were reduced, through the expanded use of more efficient methods of irrigation, to say 1,000 mm for the 247,000 hectares projected to be developed by 2020, the total diversion in the Valley would be 2,468 million cubic meters per year, or less if some of the land was irrigated by Columbia River water. This is less than the present diversion. Not only would more water remain in the river for assimilation of waste loads and for support of fish life, but the quantity of lower quality return flows would be reduced. Therefore, if the methods of conveyance, distribution and application of water improve as anticipated, water quality should also improve. The rate of improvement will depend on the rapidity with which these methods are implemented.

Given these basic physical parameters, limitations or constraints of the system, we need to concentrate on the causes of the problem, following which potential solutions and implementation strategies can be delineated.

SECTION 6

CAUSES OF THE PROBLEM

The purpose of this section is to identify the variety of causes of irrigation return flow pollution in the Yakima Valley. The major sources of the problem have already been identified; this section seeks to determine further the basic physical, economic, legal, and social conditions which contribute to the problem of water quality degradation. By identifying the roots of the problem, it will, then, be possible to develop solutions that deal with the causative factors, rather than merely referring to symptoms. Ultimately, potential solutions with such an approach will be more effective for implementing efforts.

PHYSICAL CAUSES

> There are practically but two modes of irrigation. The first is called the furrow system--the other the flooding. By the former either a rolling or flat country can be watered, by the latter only comparatively level land can be served. By means of furrow, hills sloping at an angle of 30° have been successfully watered. To prepare the ground for the furrow system all brush and large stones should be removed, small knolls and hummocks cut down, the low places filled and the ground brought to a level or even slope. To the highest point of the land to be irrigated a lateral is run from the main ditch or canal. From this lateral a head ditch is constructed, following the highest contour of the land. From the head ditch, receiving its water from the lateral, small furrows are run with an implement resembling the corn marker of the New England farmer. These furrows on level tracts are run in straight and parallel lines. Where a side hill is to be watered, the furrows are run practically parallel and upon contours. From the head ditch the water is let into the furrows by means of square wooden pipes constructed out of lath, and with such openings as to carry in the neighborhood of one square inch of water without pressure. This inch of water will follow a furrow and oftentimes successfully irrigate a stretch half a mile long by three feet wide, or over one-third of an acre (Washington Irrigation Company, 1902).

The practices quoted in the brochure of the Washington Irrigation Company describe the state of irrigation technology in 1902, in an area of limited experience with irrigation. Unfortunately, the form of irrigation described above has changed little over the ensuing three-quarters of a century. Thus, the use of furrow irrigation on steep slopes is the primary physical cause of irrigation return flow quality problems in the Yakima Valley today. The flooding mode (level basin irrigation) is now little used, indicative perhaps of the absence of level land.

The soils of the Yakima River Basin, as described earlier, are predominantly of fine sandy loam or silt loam of variable depth, usually underlain with gravel or decomposed basalt. The soils are highly erodible when disturbed. The clearing of the native vegetation from the Valley soils, their cultivation and the application of irrigation water down their prevailing slope has caused much of the topsoil to be washed to the river. As a consequence, adsorbed phosphate ions have also been carried to the river in large quantities.

Although the problems associated with the predominant method of irrigation could be overcome to some extent by careful management, the inherent limitations of the method make complete control of runoff and erosion difficult. Some of the more conscientious farmers have endeavored to farm across the slope and to reduce furrow stream size, but these are few. With the abundance of inexpensive water, there is little incentive for more intensive water control. The move to sprinkler irrigation has been motivated more by the possibility of labor savings rather than water quality considerations.

In general, the management of the irrigation system is not well suited to the soil and topographic conditions, at least not from a water quality standpoint. Streams of excessive flow rate are turned into the furrows, so that erosive velocities prevail over a considerable portion of the furrow. At the end of the furrow, the tailwater drain is often at a lower elevation than the invert of the furrow, so that furrow stream velocites increase with consequent incision at the end of the furrow. The tailwater drains themselves, running across slope without vegetative protection, often erode.

In addition to the contribution of sediment and phosphates to the return flow, caused by these practices, the contribution of nitrates is also largely influenced by management practices. Given the nature of furrow irrigation, deep percolation over at least part of the field is virtually impossible to prevent. Whenever furrow irrigation is practiced and whenever nitrogenous fertilizers are used, a portion of the water soluble nitrates will be leached from the soil profile and returned to the stream. In many instances, this is abetted by the overapplication of fertilizer, often to compensate for the amount anticipated to be leached. All in all, poor irrigation practices combine with poor fertilizer practices to cause further pollution of the Yakima River.

ECONOMIC CAUSES

The major economic causes of irrigation return flow pollution in the Yakima River are: 1) the absence of a market for allocating irrigation water; and 2) the opportunity for farmers to pass on to downstream water users part of their costs of production in the form of pollution.

Lack of a Market

The present institutional arrangement allocates water on the basis of a priority of rights rather than on the value of use. The price of water is generally the cost of its conveyance to the farm and does not represent the value of opportunities foregone. The result is that the use of water is not competitive; it is not allocated to its highest value use; and its relatively low price causes it to be excessively applied.

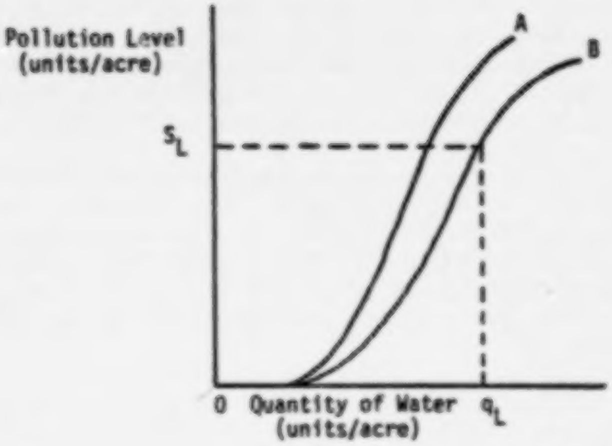
With the exception of irrigation water, farm inputs are allocated through markets. Labor and capital, for example, are allocated and priced through markets according to the value of their use. Consequently, water tends to be relatively cheap, so that profit-maximizing farmers rationally substitute water for capital and labor (i.e., water management) in the production process. The result is an overapplication of water with associated return flow pollution.

The amount of pollution resulting from the irrigation process obviously depends upon a large array of variables, such as soil type, slope of field, type of crop, stage of crop growth, irrigation management, and quantity of water applied. The present discussion focuses on the management and quantity of irrigation water as the most critical variables.

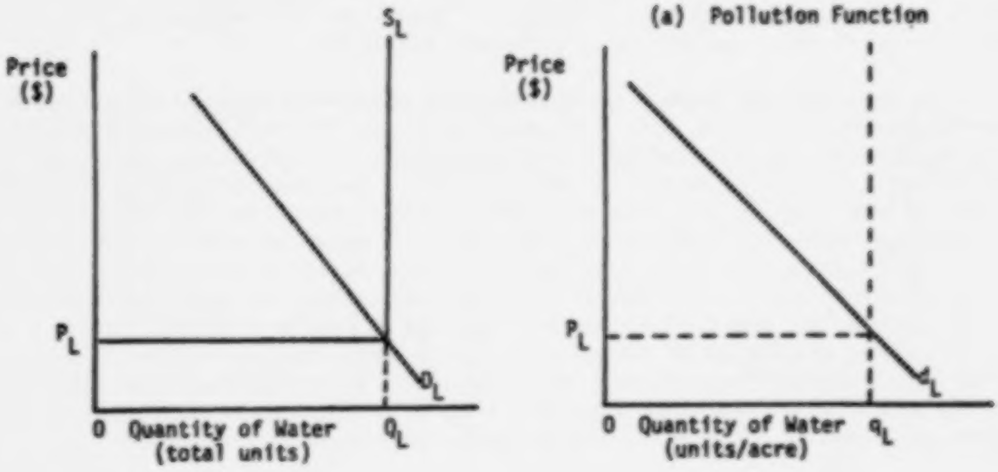
In general, the amount of return flow pollution appears to be positively correlated with the per acre (hectare) quantity of irrigation water applied, and negatively correlated with the management of irrigation water, as shown in Figure 6 (a). As water is applied beyond the consumptive use requirements of the crop (c.u.), return flow pollution tends to increase at an increasing rate with additional water up to a point of application beyond which it increases at a decreasing rate. The relative position of this relationship depends upon the level of water management, so that curve A corresponds with a low level of management and curve B with a higher level. The actual slope and shape of these curves will vary between differing areas with different physical conditions. Site-specific investigations are required to derive exact relationships; however, Figure 6 (a) serves as a general principle in order to illustrate the general conceptual relationship.

Water in the Yakima Valley is allocated according to a modification of the Appropriation Doctrine. The system of water rights established by the state water code provides for the acquisition of a right to use water on the basis of prior appropriation and beneficial use. While the Washington Code authorizes changes in users, places used, types of use, and points of diversion without loss of priority of right--provided that no injury occurs to other existing rights--a number of impediments exist which effectively preclude such transfers in the Yakima Valley.

The non-injury limitation on changes severely restricts the potential for transfers under the state code whenever holders of existing rights are dependent upon return flows in order to exercise their right. That is, in order to have a market allocation of water, there must be a clear understanding on the part of both buyers and sellers to the exact nature of the property being exchanged. Given the high degree of hydrologic uncertainties in the



(a) Pollution Function



(b) Market

(c) Farmer

Figure 6. Present irrigation/pollution relation.

Valley, clearly defined property rights do not exist. Moreover, the transaction costs of determining whether injury will occur or not are potentially so large as to create an additional impediment to market transactions.

Within Bureau of Reclamation districts, repayment contracts with farmers generally limit the place of water use to the lands classified as irrigable within the district boundaries and, thus, restrict transfers outside the boundaries. Moreover, districts have a disincentive to invest in more efficient uses of water and water recovery operations, since such additions to their supply would simply reduce the amount of water delivered from the Bureau. Districts would, therefore, not have this additional water either for irrigating new lands within the district or to market elsewhere and additional revenue would not be generated to offset the costs of any efficiency measures undertaken.

The importance of district by-laws related to transferring of water are exemplified by those in the Roza Irrigation District. In this context:

> The first three acre-feet per acre may be transferred by the owner of the appurtenant acreage thereof, to another delivery, PROVIDED: 1) the acreage to which the same is transferred is in fact farmed by the transferror as the bonafide owner or leasee thereof for the year in which the transfer is to be effective; and 2) written instructions are filed with the district and approved by its manager or secretary. Water rights cannot be transferred.

The effect of this regulation is that a water user is free to distribute his total supply to the area under his control, but he cannot sell any portion of his supply to another water user. Most of the other irrigation districts within the Yakima Basin follow a similar policy relating to water transfers. An interesting exception is the Yakima Tieton District because it uses a market system to allocate water rights within the district boundaries. The district's water supply is divided into shares, each share equaling 2,973 cubic meters (2.41 acre-feet). These shares may be freely bought and sold subject only to the ability to deliver the water to the prospective buyer. There are currently 31,430 shares held by individuals with 80 shares held by the district as a safety margin on total supply. The district manager estimated that the current market price of a share was between $500 and $600. Annual water allotments are subject to the restriction that they may be temporarily transferred only to lands under the same ownership and on the same ditch. Thus, although the district handles up to thirty transfers of water rights each year, those transfers tend to be of small quantities, closing out the water right on a small, inefficient piece of land and adding that water right to a larger irrigated acreage.

In general, then, water allocation in the Yakima Valley is accomplished by a variety of legal mechanisms. With few exceptions, the market plays no role in the water allocation process. Even where transfer of water rights is possible, it is not possible to transfer portions of the annual allotment except among lands under the same ownership.

Since the appropriation cost of irrigation water is zero and the conveyance cost per unit of water is generally constant, the aggregate supply curve in Figure 6. (b), S_L, under the present institutional arrangement, is a horizontal line at the level of the conveyance cost, P_L, out to the total quantity of water available for use, Q_L. At Q_L, the supply curve becomes vertical. That is, the relation between the amount of irrigation water supplied and the price of that water is a horizontal line at the level of the constant cost of conveyance up to the limit of supply, beyond which no additional water is supplied at any price.

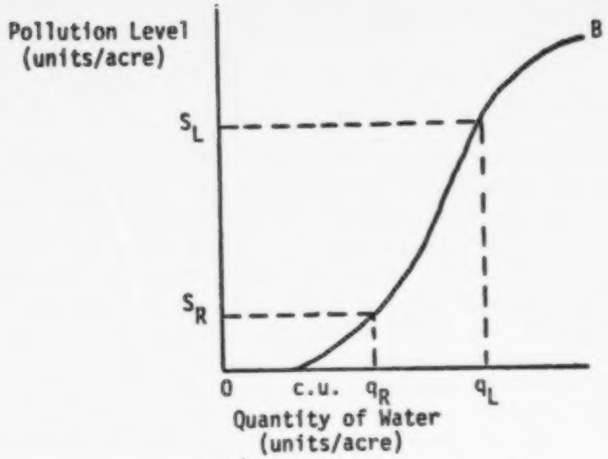
Summation of the demand of all water right holders at any point in time yields the equivalent of a market demand curve. As the demand for water in the river basin increases, the market demand curve in Figure 6. (b) shifts outward until D_L is reached. At that level of demand, the river's waters are completely allocated and no further water rights are issued.

With a normal downward sloping demand curve, d_L in Figure 6. (c), the individual farmer will rationally demand q_L units of water per acre at the average conveyance cost of P_L per unit of water. He will apply for and receive a right for that quantity as long as water is available. The actual allocation will depend on additional physical and legal considerations but the tendency will be towards an allocation of q_L units per acre of irrigation water. If the level of water management corresponds with curve B in Figure 6. (a), then the present allocation system results in an irrigation return flow pollution level of S_L units per acre.

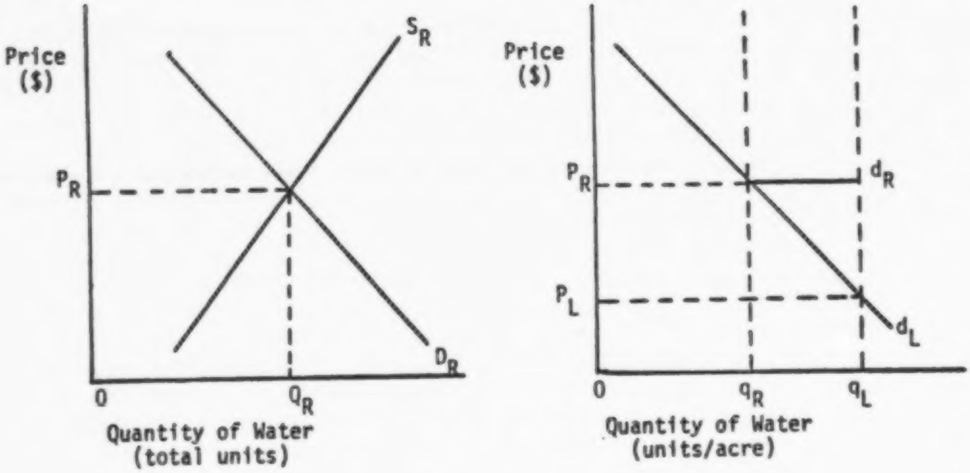
On the other hand, a market allocation of water would reduce individual farm applications of water and, consequently, return flow pollution. Suppose a water rental market is created such that non-water right holders could rent water from those with water rights without jeopardizing those rights--conditions which will be justified later. Then water right holders acting as suppliers of rental water would have an upward sloping supply curve, S_R, representing increasing opportunity costs as shown in Figure 7. (b). This supply curve represents the quantity of water that water right holders would rent rather than use at each price. The rental market demand curve, D_R, represents the aggregate marginal value product of irrigation water to non-right holders. The equilibrium quantity, Q_R, represents the amount of water right holders would rent to non-right holders.

Individual water right holders would adjust to the rental market equilibrium price, P_R, by reducing the quantity of water irrigated from q_L to q_R. That is, water right holders could realize a greater return from their right to q_L units of water per acre by reducing their irrigation to q_R units per acre and renting the surplus $(q_L - q_R)$ units per acre. The derived demand for irrigation water with a rental market, d_R, differs from the present demand curve, d_L, in that it is horizontal at the market price level beyond q_R, as shown in Figure 7. (c).

If non-right holders are assumed to have identical irrigation demand curves to those with water rights, d_L, then each non-right holder will also rationally use q_R units of water per acre at a rental market equilibrium price of P_R. The effect on irrigation return flow pollution is that each



(a) Pollution Function



(b) Market

(c) Farmer

Figure 7. Irrigation/pollution relation with rental market.

farmer would cause S_R rather than S_L units of pollution per acre, as shown in Figure 7. (a). On the other hand, there are more irrigators. The net effect of the rental market depends upon the ratio of the proportional increase in the number of irrigators to the proportional decrease in the pollution of each irrigator. If the ratio is less than one, then total pollution is expected to decline.

Externalities

Irrigation return flow pollution also results from the avoidance by farmers of some costs of production. The profit-maximizing farmer attempts to minimize production costs. In so doing, however, he may select production methods and techniques which are low cost to himself, but polluting to downstream water users. Alternative production methods and techniques may be less polluting but are of a higher cost to the farmer. By selecting the lowest cost methods and techniques, the farmer passes on part of the costs of production to downstream water users in the form of water pollution. It is difficult at this point to provide an inclusive discussion of this type of economic cause of return flow pollution because of the diverse nature of its occurrence. How costs are externalized, however, can be illustrated in several cases for the Yakima Valley.

One of the most striking initial observations of the research team in the Yakima Valley was the common practice of furrow irrigating down the slope of the land rather than contouring. Especially where slopes are steep, this practice is a major contributor to rapid water runoff and sediment pickup. In a relatively short period of time, this practice may wash away large amounts of top soil as well as the crops themselves, thus reducing the farmer's production. Why then does the farmer pursue such a practice? He does it because he not only desires to maximize revenues, but also minimize costs. More precisely, he wants to maximize the difference between revenues and costs. The farmer is, thus, acting rationally when he calculates that his profit will be greater if he adopts an easier and less costly practice of irrigating with the slope rather than across it. In so doing, however, he externalizes part of his production costs, which are subsequently borne by downstream farmers in the form of increased repair costs for pumps and sprinkler heads, and by recreationists in the form of aesthetic degradation of the river as well as reduced fisheries. If the upstream farmer were to internalize these costs, he might opt for higher cost but less polluting irrigation techniques.

Tenant farmers may also externalize some costs of production onto the landlords. As stated in Section 4, Yakima Valley has a significant amount of irrigated land owned by absentee landlords. Tenants of these lands have a relatively short time perspective regarding the use of the land which usually corresponds with the duration of their lease. Again, the tenant farmer may rationally maximize his short-run profits by extending part of his costs of production. Such a cost is associated with the long-run maintenance of the land. By adopting irrigation practices which avoid these maintenance costs, tenants pass on part of their production costs to the landowner in the form of soil erosion and loss of topsoil and to downstream water users in the form of water pollution.

LEGAL CAUSES

Under the American system of jurisprudence, the law is considered to be the socially acceptable mechanism to direct and control the activities of man in areas where conflict or need exist. Natural resources and water resources particularly have been subject to extensive legislative and judicial intervention in the attempts of man to guarantee dependability, flexibility and equity into the public and private use of the resources. Often, however, either the law lags behind social demands or it is designed to protect certain rights and privileges in conflict with those held by others. Such a situation can also arise from changing external circumstances and from the ensuing cultural lag between established practices and current conditions.

Water law, in an era of rapid social changes and of shifting emphasis to public rights and environmental concerns, is full of constraints to public interests in water quantity and quality management. In the area of irrigation return flow, the legal contributions to the quality control problems vary from state to state as the laws differ in each particular area. In Washington, and specifically in Yakima Valley, a number of basic legal causes of water pollution can be identified.

The first cause is universal throughout the 17 western states, namely, the failure to enforce the concept of beneficual use provisions of the law. The reason is twofold. One has to do with the fact that the definition of beneficial use is nebulous and, thus, lacks appropriate direction for administrators to follow or courts to interpret. The second derives from a lack of social consciousness on the part of water users so that the burden of proving nonbeneficial use is upon the state, which is really an administrative impossibility. Generally, our system of water law places emphasis upon the right to use water, not the duty to use it appropriately.

Constraints to water transfers also contribute to the problem by providing a disincentive to use water more efficiently on other lands or other uses. Water rights can be transferred with the approval of the DOE and under conditions to protect the vested interests of other water right holders. The restrictions of privately transferring the right to use water in federal reclamation projects exists under federal law based on the theory that the project was designed to irrigate X acres with Y acre-feet of water and to irrigate other or more acres will decrease some of the productivity per farm unit, provide economic benefit at taxpayers' expense, or jeopardize the following years' carry-over water supply. Consequently, in the irrigation districts of Yakima Valley, the district can reallocate the water held under water rights, but individuals cannot sell their water supply.

Finally, another legal problem that exists is the absence of specific responsibility or duty for water quality control by the irrigation districts. Their function is primarily to capture and convey their entitled water supply to district water users. This problem is amplified by the lack of a legal requirement for water quality maintenance by the Bureau of Reclamation in its repayment contract with the irrigation districts.

SOCIAL CAUSES

The problem of water quality exists in a social setting because either the members of this particular social environment do not perceive the problem *per se*, because they cannot do anything about the problem, or because they refuse to do anything about the problem. A combination of all three conditions exists in the Yakima Valley, reinforcing in turn the problematic state of affairs outlined previously. The search for social causes in water pollution can be traced at either the individual farmer level or at the organizational level, i.e., to those entities involved and responsible with irrigation management.

The Individual Level

At the individual level, there are three general categories under which the problematic conditions mentioned above can further accentuate problems of water quality: 1) individual perception of the problem; 2) the actual irrigation activity pursued by the farmer; and 3) the perception of the farmer regarding his relationship with his neighbors in terms of water quality. In essence, how individual users fit into these categories of concern will largely determine how the problem is to be defined and, then, coped with.

As a whole, there is no general appreciation by the farmers of the significance of the present problem involving irrigation return flow quality. The greatest concern is expressed by those who are being directly affected by polluted water. Yet, even these farmers will continue to utilize irrigation methods that continue to aggravate the problem. There is the common perception that the farmer has the right to use his water in a virtually unconstrained manner. In this regard, one specific source of the pollution problem is the overapplication of water; yet, farmers on the whole do not believe that they are using too much water. They use their full allotment of water in order to maintain a reserve for the dry years that they "know" will come along in the future (and which presently are in their midst). In addition, when there is extra water to be sold, even though it is at a higher price, the farmers will buy that water and utilize it in the same inefficient manner. The perception of the problem of water quality is just beginning to become an issue of public concern but responses are only now beginning to emerge.

The second category describing social conditions encouraging the problem situation is the actual irrigation activity pursued by the farmer. The critical point in this area of concern is that the farmers perceive, and rightfully so, that there is going to be a certain amount of degradation in the water quality by the mere fact that the water is simply being utilized. However, the amount of degradation that is acceptable is open to debate and subject to various interpretations. In fact, farmers were not all that concerned with water quality until very recently when the SCS initiated the Sulphur Creek Project and results demonstrated the character and extent of water pollution.

This situation is compounded by the obvious fact that many farmers value their old ways of irrigating. Many farmers perceive, whether correctly or incorrectly, that sprinkler irrigation (one of the more efficient forms of water use) is not applicable to their particular situation. In addition, a new irrigation method--trickle--was introduced into the Valley improperly and, thus, failed on many farms. The lack of success of this demonstration project was quite significant for the creation of a background of testing innovations. Trickle is starting to spread again, but unsuccessful past experiences tend to reinforce entrenched methods of irrigation as the appropriate way of conducting business in the Valley.

In addition to the specific form of irrigating, there are also many different ways to apply those forms, be they good or bad. A sprinkler system can be just as detrimental to water quality as a furrow method if it is administered poorly. It has been reported that on many of the larger operations the irrigation methods are poor due to the fact that these farms either do not employ enough irrigators or the ones that they do employ are poor irrigators to start with. The results are the same and the manner in which these farmers irrigate becomes detrimental to the meeting of adequate water quality standards. However, the question then arises as to what types of practice are detrimental to water quality and under what conditions they become detrimental. This is the crux of the problem: there has been no common way to measure an acceptable irrigation practice with regard to water quality. In its absence, conflicting or competing interpretations create a general atmosphere of distrust as to results or as to the need of alternative strategies.

This leads to the third major category of conditions that may facilitate water quality problems: the perception of the farmer regarding his relationship with his neighbors in terms of water quality. In short, there seems to be a lack of cooperation among the farmers regarding water quality. The major concern that most of the farmers have is with what happens to the water on their own farms. Suits have been filed against one another, indicating in an indirect manner the lack of "regional" concern over water quality and water use. Similarly, there is a lack of overall participation in the district management of water by the majority of users. Related to this situation is also the common perception that only 5 percent of the users are major polluters. Even though there is a widespread belief among users that it is this "other" 5 percent responsible for water quality woes, the research team has not seen any documentation on how such a figure has evolved or what is the basis for such a belief. Under such conditions, it is obvious that problems of irrigation return flow are currently perceived as of a narrow individualistic matter resulting from particular water practices and not as a matter requiring a regional basis of understanding.

The Organizational Level

Regarding the organizational entities involved with irrigation, two categories seem to be critical with regard to water quality problems in irrigation return flow: the integration of those organizations and their respective authority with regard to irrigation quality. It is within such an organizational structure that standards of behavior regarding alleviation of irrigation return flow problems can be established, which in turn can contribute to a change of prevailing perceptions by individual users regarding the nature and extent of the problem.

The integration of these organizations is based heavily on the degree and type of communication existing between them. In the Yakima Valley, there is little communication between the irrigation districts, and most of it was started a few years ago. The same situation exists between the districts and the farmers. In fact, many farmers interviewed did not know the members of the board of control that looks over their irrigation district. Where there is need for the greatest communication possible, present linkages are weak at best.

Information that does reach down to the grass roots level is also selectively distributed. Knowledge of P.L. 92-500 rests on a few individuals. There is one individual who knows the law extremely well and he is the local opinion leader with regard to irrigation water quality. He has the ability to sway the local people as to their perceptions of water quality according to how he sees the law. As an influential "gatekeeper," he provides the ultimate interpretation of what is the "problem" and what solutions, if any, are needed.

Coupled with the general amount of information distributed is the fact that many farmers cannot transfer basic information regarding farm management procedures to their farms for practical use. Finally, the means to achieve irrigation control, when attempted, runs into financing problems with either not enough funds or with an improper method of allocating those funds. For instance, the Agricultural Conservation Program funds are allocated on a congressional calendar and not on a farmers' calendar, which means that those funds cannot be utilized at the best possible time.

In short, the communication and integration networks involving the various organizations working with irrigation return flow quality are not satisfactory in that the quantity of information distributed and the destination of that information are not being fully exploited or appropriately utilized.

In addition to the integration of the various organizations in the Valley, a second important differentiation has to do with the type of authority regarding implementation of water quality control measures. In the Yakima Valley, this issue of authority is a hotly debated item. As indicated previously, irrigation districts in the Valley see their authority ending at the farmer's headgate while the DOE states that they do indeed have authority over water management on the farm. Due to the position of the administrators of the various districts--that of being elected by the farmers themselves--this question of authority is indeed a sensitive one. Not wanting to upset the status quo and, thereby, jeopardize their jobs and positions, the administrators of the irrigation districts are not going to readily accept any program that demands them being enforcers of water quality standards.

This question of not utilizing one's full authority involves also the DOE. The agency's priority is on voluntary change that will enhance water quality through programs, educational facilities, along with other "positive" reinforcements. Administrators in DOE view enforcement as a last resort measure. The big question regarding one's authority is not only whether one actually has it but also how is that authority to be implemented. These questions as well as others, such as, should the laws be tougher so as not to allow violations of the 160-acre limitation as easily as they do now, must be clarified if any meaningful water quality program is to be initiated. As of now, there is focused uncertainty regarding whether organizational authority allows the thrust of any new program to be undermined by having its energy dissipated in areas of concern that are related to water quality control but which, at the same time, are not directly related to the solving of those problems in an efficient and effective manner.

Having described, then, the nature and causes of problems concerning the quality of irrigation return flow, we should turn our attention to potential solutions with the help of which a coherent process of implementing legal imperatives can be accomplished.

SECTION 7

IDENTIFICATION OF POTENTIAL SOLUTIONS

The purpose here is to identify potential solutions to the irrigation return flow problem in the Yakima Valley. In the framework of the approach established, these solutions are initially identified with respect to the particular causes of the problem as specified in the previous section. This section concludes with a brief discussion of possible combinations of individual solutions that could deal simultaneously with several of the physical, economic, legal, and social causes of the problem.

PHYSICAL SOLUTIONS

A comprehensive review of alternative technological solutions to irrigation return flow quality problems in the Yakima Valley has been presented by CH2M/Hill, Consulting Engineers of Bellvue, Washington, in their report "Agricultural Return Flow Management in the State of Washington," of April 1975. Much of the information on technical solutions that follows has been drawn from that report and supplemented where appropriate. Costs are of a preliminary nature, with capital costs considering only labor and materials and annual costs considering operation and maintenance, including power, but not amortization of capital unless specified.

Water Delivery Subsystem

Improvements in distribution systems would increase the efficiency of these systems and permit a reduction in the amount of water diverted. More water would be available for instream uses and for assimilating the present waste load. A reduction in the quantity of irrigation return flow would also be achieved.

Irrigation system improvements would prevent wastage of water from the system due to seepage and operational spills. Nearly all canals and laterals in the Valley are unlined. Lining or piping would reduce losses due to seepage and phreatophyte consumption. Additional check structures, or a regrading of canals, would allow gravity diversion heads to be maintained without filling the canals with excess water, ultimately to be wasted. Automated controls would prevent operational wastage at those times when district personnel are not on hand. Lining, construction of control structures and regrading could be carried out conjunctively.

The lining of laterals, or conversion to pipelines, would not only reduce seepage and consequently subsurface return flows, but would also be beneficial in providing additional water control. Another important aspect of water control is providing flow measuring devices, particularly at diversion points along each lateral and at each farm inlet. Additional water control would allow a significant improvement in farm irrigation application efficiencies.

Most of the existing delivery systems divert from the river many miles upstream of the point of need. Much of this water could be left in the river for a considerably greater portion of its length by diverting from a lower location. In particular, areas located across the river and served by siphons could be served by pumping stations at the siphon location. Hydraulic turbines could be replaced by pumps to further reduce wastage from the system. The costs of such pumping plants could be compared with the costs of canal lining in order to evaluate whether or not this is a viable alternative.

Reuse of irrigation return flows on an irrigation district basis could be adopted to recover water, soil and fertilizer that otherwise would add to the pollution load of the river. Waste water could be pumped to canals or laterals for use further down in the system. This occurs to some extent at the present, with return flows from higher irrigation districts augmenting the flow in the canals of lower districts or units of the same district.

The use of ground water in conjunction with surface water supplied would allow a reduction in surface water deliveries, thereby maintaining a larger flow in the river. In many areas in the Valley, the high ground water levels are a direct result of irrigation. The ground water could be pumped to adjacent canals and laterals during mid-summer when water supplies in the river are diminished, effectively moving the point of diversion further down the stream.

During the early part of the irrigation season, flows in the river generally exceed the irrigation requirements as well as providing an abundant flow for fish life. Seasonal runoff could be more evenly distributed by providing additional storage capacity on upstream reaches of the river. Summer flows could be maintained at an adequate level to provide a suitable habitat for fishlife.

On-Farm Subsystem

The earlier discussion on the effect of irrigation on the river's water quality has already shown that irrigation was a major cause of water quality degradation in the Valley. As would be expected, within the irrigation system the use of water on the farm is the major cause of degradation. This degradation could be alleviated by improving water application methods and practices in order to reduce both surface and subsurface return flows, thereby controlling erosion and in conjunction with modified fertilizer practices, reducing nitrates and salt loads in subsurface return flows in the Yakima River.

Improved water application techniques and scheduling of irrigation applications would allow a reduction in the amount of water delivered to the farm . Surface methods of irrigation on light soils require that an excess of water be applied at one point in the field to ensure that the minimum crop requirement is supplied at another. The higher uniformity of more efficient irrigation methods allows water applications to match plant consumption more closely.

Two of the most common application methods for reduction in the quantity of applied water are sprinkler and trickle irrigation. Both methods can operate at high efficiencies on light soils (i.e., a high percentage of water diverted to the farm is used by the crops). The amount of applied water can be controlled so that deep percolation losses are comparable to the leaching requirement necessary for maintaining a salt balance in the root zone. Benefits accrue to the farmer from savings in fertilizer and soil that would otherwise be eroded from the land. The quantity of water handled is also reduced. Water quality is enhanced by the elimination of soil from the surface drainage water and fertilizer from both surface and subsurface drainage flows. The district benefits from the reduction in ground water buildup in many instances has led to the necessity of artificially draining waterlogged areas.

Recirculation of irrigation tailwater on individual farms could also be used to salvage water and nutrients. The surface irrigation runoff could be collected in a tailwater pond and pumped back to the head of the irrigation field or to an adjacent field for reuse.

Irrigation scheduling allows the optimum quantities of water to be applied at the optimum time intervals to conserve water and maximize economic returns. Farm returns are increased from the reduced quantity of water handled, reduced leaching of plant nutrients and erosion of topsoil, and from the reduced incidence of plant diseases associated with waterlogged soils. The reduction in soil and nutrients lost from the farm also benefits water quality.

A reduction in the amount of sediment leaving the farm can be accomplished in two ways: 1) by preventing erosion in the first place; or 2) by preventing eroded sediment from reaching the drains. In addition to the means discussed above for preventing erosion, contour plowing also offers a possibility. Where steeper lands are used for row crops, the rows may be plowed to more closely fit the contours of the land, thereby reducing velocities and erosion potential. With furrows across the slopes, the tailwater drains must of necessity be down the slope. The increased potential for erosion in the tailwater drains would have to be countered by using either a collector pipe at the end of the field or by grassing the tailwater drain. Considerable erosion which occurs in many tailwater drains at present could be reduced by these means. To prevent sediment from reaching the drainage ways, sediment ponds may be constructed at the lowest point in the field. The recovered sediments may be spread back on the field at the end of each season, although this is a very expensive operation.

Fertilizer applied to the soil in excess of crop requirements represents an economic loss to the farmer and degrades the quality of streams receiving return flow water. Both losses can be reduced by using soil analyses to determine the correct amount of fertilizer to apply, by timing applications to reduce the time available for fertilizers to be leached from the soil, and by placing the fertilizer where it is readily available to the roots. However, the most expedient means for achieving high fertilizer use efficiency is to adopt improved water management practices which provide high irrigation application efficiencies.

Return Flow Subsystem

Sediment and nutrients can be removed from return flows by settlement which may be accomplished by either slowing velocities or retaining the water completely. Velocities could be slowed in the drains by reconstructing them with a wider section and a flatter gradient and providing drop structures where necessary. The drain bed and banks could be grassed for greater retardation of flows. Alternatively, settlement could be achieved by routing return flows through treatment ponds with sufficient time of retention to precipitate sediment and remove nutrients. In both cases, sediment would have to be periodically removed, and in the case of settlement for nutrient removal, the aquatic vegetation would have to be periodically harvested. To decrease the time of detention for sediment removal, and hence reduce the size of pond required, chemical additives may be necessary to facilitate sediment flocculation.

More advanced treatment could be considered for the removal of phosphorus, nitrogen, bacteria, and salts. Advanced treatment methods have been developed in recent years for the removal of nitrates. The two nitrate removal treatment methods to be considered are algal stripping and denitrification. Also, advances in the treatment of saline water have been made in recent years; however, the problem of large flows and low salinity concentrations in the Yakima Valley would make desalination of return flows extremely expensive and not economically feasible.

ECONOMIC SOLUTIONS

With reference to the major economic cause of irrigation return flow pollution outlined previously, there are two respective economic solutions: 1) establishment of a market for irrigation water; and 2) internalization of production costs through taxes and/or subsidies.

Water Rental Market

A market for irrigation water can take many forms. The intent here is to identify that form which appears to be the most applicable and implementable. While the establishment of a water market will alter the present institutional arrangement, it seems desirable from a practical standpoint to alter that arrangement as little as possible in order to assure its acceptance.

In order to minimize disruption of the present institutional arrangements for allocating irrigation water, the market form identified as having the most potential is a water rental market. Under such an arrangement, a water rental market would accept the present structure of water rights and allotments and would permit the rental of surplus water to the water users without jeopardizing these rights and allotments.

A water rental market could be established by removing the present legal and physical uncertainties associated with such transfers. The hydrologic properties of the water system would require more detailed specification. This is largely due to the need to satisfy legal requirements that transfers not injure other water rights. Transfers might be restricted to the amount previously used consumptively; however, it is possible that a more detailed hydrologic specification of the system would show that with a large number of both upstream and downstream transfers that negative effects of transfers would be canceled by positive effects.

The demand for rental water would represent the water's addition to the total value of output per additional unit of water. The market supply schedule would represent the water right holder's increasing opportunity cost of using the water himself rather than renting it. The market equilibrium price, then, would be greater than the current costs of conveyance. Those demanding the supply would have an economic incentive to use water more efficiently. That is, a rental market would increase the price of water to its marginal value in production and would, thus, encourage more use of labor and capital (i.e., water management) in combination with the water, thus reducing return flow pollution.

Taxes and Subsidies

A market allocation of irrigation water would most likely not be sufficient to correct for all return flow pollution. While a market could be expected to significantly reduce the problem, water users would still have an economic incentive to externalize all possible costs of production, including the costs of controlling pollution. That is, by avoiding costs associated with the use of water in production, water users can increase the difference between their revenues and costs and, thus, increase profits.

In a market transaction, one party incurs costs in order to obtain benefits, while the other party receives payments in exchange for goods or services. The interdependence of the parties is illustrated by a closed feedback loop, as shown in the lower portion of Figure 8. The purchaser of an agricultural product is expected to pay the full cost of the item and, in turn, he expects to get full and sole claim to its use.

Sometimes, however, payments for an item do not cover all of the costs. While agricultural producers and consumers regulate each other through the interaction of the supply and demand mechanisms of the market, farmers also produce water pollution which affects the welfare of downstream water users. Within the market structure there is no mechanism by which downstream water users can close the pollution loop. Therefore, the farmer and the farm product consumer reach an equilibrium position different from that which would be optimal if all affected parties were included.

The function of government is to close the loop involving pollution. By receiving complaints and transforming these inputs into regulatory intervention (i.e., taxes, subsidies, laws, or regulations into the producers' operation), government closes the loop. The farmer is now forced to include the interests of downstream water users as well as those of consumers of his

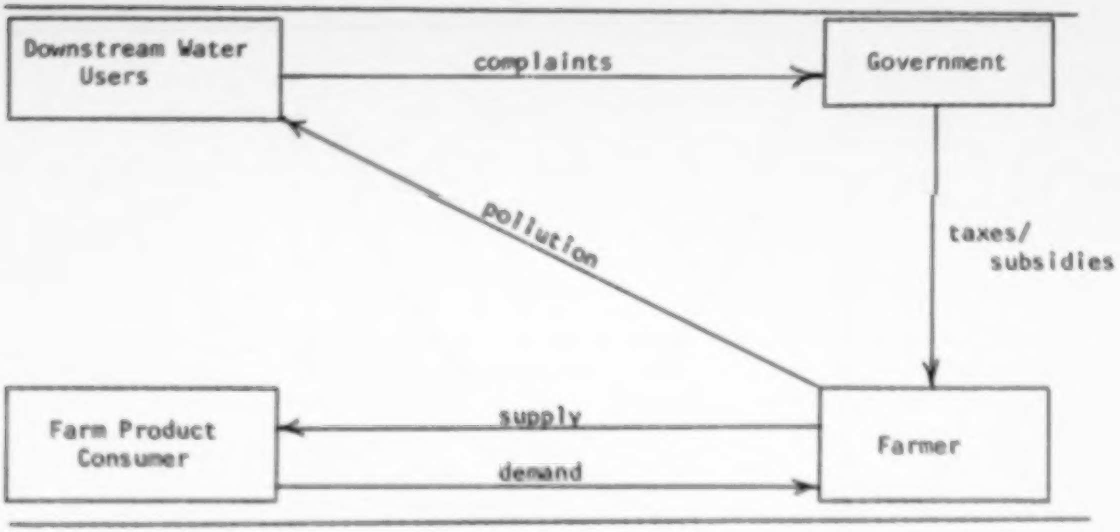


Figure 8. Exchange, externalities and closing feedback loops.

produce in his decision-making process. Conceptually, taxes and subsidies can be examined through the use of Figure 9. Hypothetical marginal cost and demand (i.e., market benefit) curves for increasingly clean water are shown in this figure. The optimal level of clean water is at Q_o on the horizontal axis. To the left of this amount, benefits would exceed costs of additional clean water, while the converse is true for amounts greater than Q_o.

The polluter can be either forced or "bribed" to internalize his costs of production. He can be forced through the use of a tax on untreated or unacceptable return flow. As long as the tax exceeds the marginal cost of clean water in Figure 9, it will be cheaper for the polluter to clean the water rather than pay the tax. Therefore, the tax should exceed the marginal cost up to Q_o. On the other hand, a subsidy can be used to bribe the polluter to clean the water. The amount of the bribe or subsidy would have to exceed the marginal cost but not the marginal benefit of the clean water up to Q_o.

LEGAL SOLUTIONS

The law, as a tool to guide or direct social activity relative to areas of known or potential conflict, cannot operate in a vacuum. It must be both considerate of and consistent with physical and socio-economic conditions and serve as a facilitator to a desired end result and not reason for either achieving the problem or the solution. Unfortunately, as discussed in a previous section, the law often becomes a constraint as needs and conditions change, requiring amendments, additions, or deletions to remove legal hindrances to the solution of water quality problems. For irrigation return flow

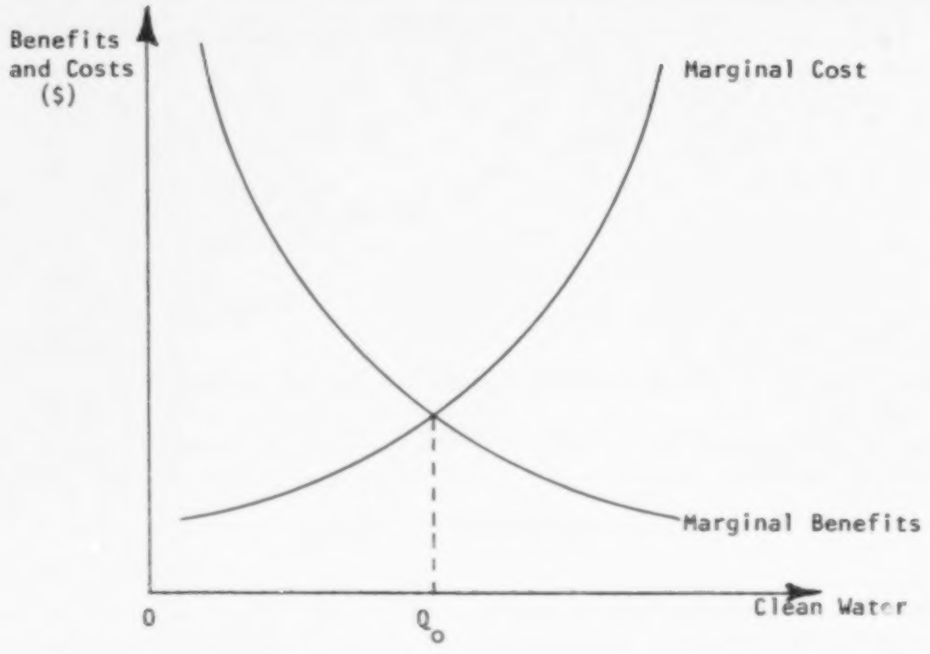


Figure 9. Marginal benefits and costs of clean water.

quality control in the Yakima Valley of Washington, several potential legal solutions exist which would facilitate improvement of the present situation.

One of the first legal causes described above was the failure to comply with or enforce the beneficial use concept under which water is allocated and the exercise of the right to use follows. Cases in Washington and other western states reflect the difficulty of enforcing this general concept. It is suggested, therefore, that the DOE develop and adopt criteria for beneficial use as an agency rule or regulation. These criteria for use will in effect define the standards of water use efficiency in the conveyance and application of water under the exercise of a water right relative to quantity of diversions, use and quality of discharge. They will also provide the basis for shifting the burden of proper use of the public resource upon the benefactor (both purveyor and user) and in essence identify the duty for delivery, use and removal of water.

A second legal solution is to merge the economic benefits from a more liberal transfer policy into legal guidelines that still provide the protection from impairment to other water right holders. This would require, in the case of federal reclamation project areas, the adoption of an incentive mechanism to encourage water users to "market transfer" some of their water through the district. For example, a lower or credit assessment system can be worked out as a strategic intervention for alleviating water quality problems.

Some programs already exist which provide no- or low-cost funding for improving the water delivery, application and removal subsystems. These state programs, in conjunction with the federal SCS and ASCS programs, are generally oriented toward quantity improvements. It is suggested that the water resources revolving fund in Washington be amended to broaden its scope to: a) provide funding to individuals; and b) for not only improvements as they affect the quantity of water but also for improvements that enhance the quality of return flows.

SOCIAL SOLUTIONS

It is important to remind ourselves at this point that "solutions" are seen as potential responses emanating from the general causative factors identified in Section 6. In this regard, solutions to problems of irrigation quality control from the social standpoint evolve from the very social conditions that allow such a state of affairs to exist. Therefore, possible solutions that may contribute to changes in present social conditions, vis-a-vis water quality, must have two points of attack: the individual and the organizational setting related to irrigated agriculture.

The Individual

Among the potential solutions in this area, two are aimed at the existing perceptions of the water users. A first approach would involve the establishment of a comprehensive program that would demonstrate the significance of the problem of irrigation return flow quality. In short, people must become aware that a problem does exist. Steps are now being made through various mass media, public meetings, projects, and so on to expose the population of the Valley to the problem, but progress has been intermittent. In talking to farmers in the Sulphur Creek area, which is the main point of a current demonstration activity, there are still responses from violators indicating that they had no problem, or reactions from a number of farmers to the extent that they were only concerned with their own farms. In expressing concern about the situation, it must be remembered that the agencies involved in this awareness program must present the "true" situation and its consequences. They must lay out the evidence, a solid basis of data and present to the public a strong documented case with no exaggeration or, at the other end, soothing underestimation.

In addition to making people aware of the problem, any program of potential solutions must also show how present irrigation practices contribute to the problem. In order to do this, a common definition of intolerable degradation must be clearly established. A common definition means standards that can be accepted by a consensus of the involved public, i.e., along technological, legal and socio-economic conditions. The Sulphur Creek Project should provide a good baseline for such a solution. At the same time, research must continue on all types of irrigation in order to show the range of practices leading to more efficient water use. For example, it has been stated that there is a lack of research in furrow irrigation. This should be rectified because even though the Valley is converting rapidly to sprinklers, no one can say if pollution will stop with a significant number of people still remaining with furrow irrigation. There are people who will not adopt sprinkler irrigation, so that alternative forms of furrow irrigation need to be developed.

Regarding the interrelationship among the farmers in terms of water quality management, proposed solutions aiming at making people aware of the problem should also emphasize the regional aspect of such a problem. People must realize the extent and complexity of the problem before they will even start to be concerned about the "other" farmer. Finally, there should also be a program that will promote greater farmer participation in district matters. It is through such a participation that farmers can visualize and comprehend the total situation, gain a more regional grasp of the problem, and, thus, be able ultimately to develop an implementable comprehensive program of solutions concerning problems of return flow.

In summary, solutions that emphasize the individual component of a program around social conditions include:

a. development of a comprehensive regional program to demonstrate the significance of the problem of irrigation return flow quality;

b. manifestation of how the present irrigation practices contribute to the problem of irrigation return flow quality;

c. establishment of a common definition of intolerable degradation of water quality, involving technical, legal and socio-economic criteria;

d. promotion of further research on all types of irrigation methods, i.e., sprinkler, trickle, furrow, etc.; and

e. encouragement of more active participation by the farmers in irrigation district matters.

The Organizational Setting

No matter how much emphasis one places on the individual farmer, if the organizational component of the social system does not support such effort, then the effectiveness of individual programs will diminish significantly. A critical approach, then, is to establish also a regional authority in order to coordinate all activities regarding irrigation. This authority can emerge from the present institutional structure by combining existing organizational entities involved with irrigation; or, create a new one in the Valley. In either case, such an entity will serve as an information control and dissemination center, with powers for enforcing regulations and initiating activities. At the same time, it would be a forum for anyone concerned about irrigation, for obtaining appropriate answers or for elaborating the details of proposed policies.

In addition to this overriding solution, a number of other approaches to the problem focus on the organization-to-farmer linkages. In this regard, a first solution is to make more people knowledgeable about the law. The information control in the Valley is currently too narrowly based; more alternatives and options as well as points of view on the issue of irrigation return flow quality control must be presented. A second solution with regard to linkages is to create a viable program for disseminating information to the farmer. There is a good start by the SCS, but more resources must be rallied for expanding this informational and educational program. Of critical concern is that not only should the information be made available to the farmer, but that also the farmer should be able to transfer this knowledge to his own farm. This follow-up program (and monitoring of effective adoption) is by nature expensive; but consideration of alternatives and follow-up activities will put this program into perspective and lead eventually to more successful implementation efforts.

From the general literature, it is known that even though one presents all the information about a program to an individual, it does not necessarily follow that that individual will adopt the program. Enforcement of the law and of regulations must be taken into consideration if the problem of irrigation quality control is to be effectively solved. At present, there is debate and confusion as to who has the proper authority to enforce management criteria over irrigation water. This confusion must be cleared up and a clear-cut authority structure must be established if implementable approaches are to be pursued. The establishment of a coordinating and enforcement organization must be established, accompanied by clearly defined and widely accepted standards and means of implementation. A particular law that should be observed is the 160-acre limitation. If enforced, it could eliminate many of the problems associated with farmers trying to farm too much land. In short, an enforcement structure must be created to help induce cooperation for the various irrigation return flow quality control programs.

In summary, the solutions that emphasize the organizational component in any approach concentrating on social conditions include:

a. the establishment of a regional authority over irrigation;

b. the need for more people to become knowledgeable about the law and regulations regarding irrigation return flow quality;

c. the elaboration of a viable program for information dissemination and utilization;

d. the promotion of a clear-cut authority structure enforcing laws and regulations dealing with irrigation return flow quality; and

e. the enforcement of the 160-acre limit.

Finally, the previous brief discussion on social solutions to problems of irrigation return flow quality points out that when all is said and done, the heart of the matter is resistance by the public as a result of disagreements as to the existence or extent of the problem and as to perceived advantages from a variety of solutions. But, more important, "solutions" do not operate in neat categories, or hierarchical systems of categorical approaches. Technical, legal, economic, and social approaches are all intertwined with limitations, overlaps and trade-offs within and between categories.

There are innumerable possible combinations of solutions to the irrigation return flow problem. Obviously, most adjustments suggested here could not be implemented independently of other physical, economic, legal, or social concerns. Packages, or combinations of solutions, however, are difficult to construct since they tend not to be generalizable, but situation-specific. In this respect, one cannot provide a complete listing of such combinations. Instead, some brief illustrations may show the types of mixes which would be likely and the realistic adjustments that must be made if implementation steps are to be followed.

Starting with the suggested physical on-farm improvements, it can be seen that other measures would have to be incorporated in order to create a successful program. Implementation of on-farm improvements would require an economic scheme for cost-sharing such that the distribution of benefits and costs would be equitable. Simultaneously, legal issues relating to water rights and possible changes in those rights must also be dealt with. Finally, perhaps the most difficult problem involves the social acceptance of such a plan as a result of persuasive factors for adopting changes and for establishing new practices as part of a new social context.

The suggested water rental market solution is also not feasible by itself. It would also require a legal specification of water rights and permissible quantities of transferable water. Social acceptance, as always, is a problem. Finally, physical facilities for accommodating transfers would be required, and, therefore, technological measures must be incorporated in any envisaged holistic approach.

There is no need to provide exhaustive lists of examples. The point remains, the need for combined approaches or solutions. Given the thrust of this research, the emphasis of further analysis rests on the assessment of potential solutions through field testing in order to arrive at a consensus of packages of appropriate solutions; evaluate acceptable approaches; and finally, increase the credibility of building a process of implementation through a combination of what is theoretically sound, realistically practicable and socio-economically attainable. It is this last quest (and final section) that constitutes also the core argument of this research.

SECTION 8

ASSESSMENT OF POTENTIAL SOLUTIONS

Following the identification of potential solutions for return flow quality problems in the Yakima Valley, the research team directed its efforts to evaluation. It was understood that alternative solutions would be more or less acceptable (and thus implementable) depending on their impacts on the affected parties. Assessment procedures were devised to determine technical, economic, political, and social acceptability of alternative solutions. These procedures involved assessment and evaluation by: a) the project team; b) state and federal agency personnel; c) irrigation water management; and d) water users.

The following discussion details the results of the assessment process. The discussion is organized in the order that the assessment process took place. In this sense, the exposition that follows begins with the evaluation of potential solutions by the research team; field assessment ("testing") of proposed solutions; and finally, an evaluation of the assessment process and the final evolution of combination of solutions.

EVALUATION BY RESEARCH TEAM

Physical Evaluation

Water Delivery Subsystem--

System Rehabilitation--Annual irrigation water distribution, as shown in the U.S. Bureau of Reclamation Project Histories, indicates that losses from water diverted to USBR project areas in the Yakima Valley generally average about 30 percent. In many cases, it is difficult to separate these losses into operational spills and conveyance losses, although it would appear that the latter would constitute about 80 percent of the loss, i.e., 20 to 25 percent of the water diverted is lost to seepage.

Most of this seepage could be prevented by lining or piping canals and laterals. Many of the districts have a continuing winter program of lining those reaches showing the most significant evidence of seepage. As well as saving water, the lining and piping reduces annual operating and maintenance costs, and makes available land previously occupied by larger open canals and service roads.

The majority of operational spills occur early and late in the season when irrigation requirements are lower and high flows must be maintained in the canals to provide sufficient head for gravity diversions. Additional check structures would in many cases provide the required head without running unnecessary water through the canals. Alternatively, the canal grades could possibly be flattened during the rehabilitation program to raise the canal above existing levels, with the decrease in capacity due to flattening more than compensated by the increase due to the reduced friction of canal lining. The long reaches of canal with adequate gravity diversion head would reduce the need for check structures, while necessary check structures could be automatically or remotely controlled to provide the desired head regardless of flow.

A detailed investigation would be required to evaluate the costs of rehabilitating the various irrigation systems and to determine the economic benefits to the districts. The effect on water quality would be to leave more water in the river, particularly in the reach below Sunnyside Dam, to assimilate present waste loads and to provide a more viable aquatic environment.

Similarly, more water could be left in the river by pumping from a location further downstream rather than by diverting from the upper reaches. Those areas which are located across the river from the main body of the irrigation area in the Sunnyside District, and which are served by inverted siphons under the Yakima River, could be served by pumping stations located at the siphons. In addition, hydraulic turbines could be replaced by conventional pumping plants to eliminate the associated waste. CH2M/Hill (1975) has calculated costs for these alternatives at a number of locations.

An economic analysis would be required in order to evaluate which alternative is more feasible--lining (or piping) the main canals or constructing pumping stations. Each alternative would accomplish roughly the same objective of alleviating seepage losses from the upper reaches of the main canals; however, lining these upper reaches would still result in some seepage losses (e.g., through cracks).

A separate analysis is required for the benefits that would result from lining or piping the irrigation laterals which convey water from the canal turnouts to the farm fields. The lining is, of course, highly beneficial in reducing most of the seepage losses from a lateral. Equally as important, however, is the role that rehabilitated laterals can play in providing the necessary water control that allows higher farm irrigation application efficiencies. The inclusion of flow measurement structures and water control structures as part of lateral rehabilitation provides some of the tools required for "tuning up" present on-farm irrigation methods, as well as making physical modifications to present irrigation methods more feasible. Thus, an analysis of lateral rehabilitation should be undertaken hand-in-hand with the analysis for improving on-farm irrigation methods and practices.

Reuse of Return Flows--Much of the return flow within the Valley is reused by districts diverting further downstream. However, if return flows could be diverted for reuse before reaching the river, the waste load they carry would be prevented from entering the river. The irrigation diversion would also be reduced.

According to CH2M/Hill (1975), only the return flows of Sulphur Creek drainage and Granger Drain warrant consideration for reuse. Apart from some minor gravity diversions to the Sunnyside and Roza canal systems, approximately 4.1 m^3/sec (145 cfs) of Sulphur Creek drainage water could be reused for a total capital cost of $1,800,000 ($160 per ha or $65 per acre) and an annual operating and maintenance cost of $44,000 ($3.70 per ha or $1.50 per acre). Approximately 0.10 m^3/sec (20 cfs) could be pumped from Granger Drain to Granger Canal with a capital cost of $115,000 and an annual cost of $12,500. This alternative would be of little direct economic advantage to the water users. (In fact, water users currently being delivered water comprising some return flows would rather do without such flows, to avoid contending with the associated sediment loads). The effect of reusing return flows would be to reduce wasteload flows by almost 50 percent on Sulphur Creek and approximately 70 percent on Granger Drain.

Conjunctive Use of Ground Water--Potential exists in many parts of the Valley, particularly in the Wapato Project area, to irrigate with the good quality ground water available at shallow depth. Although the ground water salinity is 2-5 times greater than the average salinity of the Yakima River, the water is suitable for irrigation. This water could be pumped directly to the fields or into adjacent canals and laterals for distribution. The former method is currently being used to some extent to eliminate the cost of piping water to sprinkler systems. The major water quality benefit of the river would be to reduce the quantity of diversion, using more saline ground water return flows for irrigation, and providing the control (pump) for achieving higher irrigation application efficiencies. Additional benefits would accrue to the return flows if the water table were lowered sufficiently to eradicate phreatophytes and hence prevent the concentrating effect caused by their consumption of water. The loss of the wildlife habitat and aesthetic value provided by the phreatophytes would have to be considered.

The primary value in using ground water for district operations (pumping ground water into canals) would be in allowing more water to remain in the river. However, greater benefits can be achieved in using ground water as irrigation supplies for pressurized systems, such as sprinkler and trickle irrigation.

Additional Storage Capacity--Additional storage capacity has been proposed on the Yakima River and its tributaries to capture early season runoff which at present cannot be fully regulated. Most of the investigative work has been centered on enlarging Bumping Lake on Bumping River, a major tributary of the Naches River. The active storage capacity would be increased from the present 41.6 X $10^6 m^3$ (33,700 acre-feet) to 565 X $10^6 m^3$ (458,000 acre-feet). The USBR has estimated that construction would cost $24,897,000, of which $19,561,000 has been allocated to fish and wildlife enhancement (1965 cost figures). Other possibilities considered for augmenting the supply of regulated water include a 64.2 X $10^6 m^3$ (52,000 acre-foot) reservoir on the Teanaway River, a 358 X $10^6 m^3$ (290,000 acre-foot) reservoir on the Naches River, construction of a lower outlet in existing Cle Elum Lake to utilize 114 X $10^6 m^3$ (92,500 acre-feet) of water and subordination of the Wapato power right on the Naches River to permit storage during periods of low runoff.

All of the measures described above would permit a greater degree of regulation, allowing more of the early season flows to be saved for later in the season to maintain a viable aquatic environment. The quality of return flows might be slightly adversely affected, as more water may be available for farm use in dry years than is currently available. This would depend on the amount of the additional regulated flow which was devoted to irrigation compared to fish and wildlife enhancement. If most of the water was devoted to the latter, there would be little effect on return flows and the ability of the river to assimilate waste loads carried by return flows would be enhanced. Also, if additional storage regulation was undertaken in conjunction with lateral rehabilitation and improved on-farm management practices, then the quality of irrigation return flows would be enhanced.

On-Farm Subsystem--

Contour Furrows--Water velocities within furrows (rills) in some fields in the Yakima Valley have been observed to be sufficiently high to cause supercritical flow conditions within the furrow. The high furrow velocities associated with the irrigation of many of the fields causes large amounts of sediment to be carried from the farms in tailwater runoff. These velocities could be reduced by reducing the slope of the furrows, aligning them across the slope rather than downslope. The furrows would need to be sufficiently deep and the furrow stream sufficiently small to avoid overtopping. A washout may otherwise occur, as one row overtops into another, successively washing out furrows down the slope. The soil loss in this case could be higher than under existing practices. In addition, rebuilding of the furrows could cause severe damage to the existing crop. Notwithstanding, furrow irrigation across the slope is used in many areas in the western United States and does offer the potential of reducing erosion on farms in the Yakima Valley. In some instances, the furrows would not necessarily need to follow the contours of the land. By plowing at right angles to the existing (downslope) direction, a rectangular plowing pattern could be maintained while having a flatter furrow slope. In other instances, if the contour were not followed, extensive landlevelling would be required in the new direction of the furrows.

The cost of irrigating across the slope would depend largely on the topography. If earth moving were necessary to allow straight furrows, costs would be relatively high. Alternatively, if the furrows were to follow the land contour, the cost of land preparation each season would be high. In either case, more attention would be required during irrigation. In addition, as the head ditch would be required to run downslope, additional check structures would be required or gated pipe would have to be used. With furrows running across slope, the tailwater drains must of necessity run downslope. To prevent erosion in these drains, additional improvements may be necessary.

The potential benefits to the farmer would be in saving of topsoil and a reduction in fertilizer losses. Less water might be used for irrigation and there would be some potential for increased crop production. Water quality would benefit from the reduction in sediment; however, the additional revenue to the farmer resulting from increased crop production and lower maintenance costs may not offset his additional capital and/or labor costs.

Tailwater Drain Improvements--Considerable erosion presently occurs in many of the tailwater drains carrying excess irrigation water from the fields. In some cases, collector pipes have been buried at the end of the fields to prevent this erosion. Inlets collect water from several furrows and periodically drop it into the collector pipe which safely carries the water to a drain. Alternatively, the tailwater drain may be grassed for erosion protection. The grass cover reduces velocities, thereby preventing erosion and allowing sediment to settle.

Costs for tailwater drain improvements have been estimated by CH2M/Hill (1975) to be \$75-\$150 per ha (\$30-\$60 per acre) for collector pipes with negligible annual costs, and about \$7.50 per ha (\$3 per acre) for grassed tailwater drains with an annual cost of \$2.50 or \$5 per ha (\$1 to \$2 per acre).

Although these improvements would benefit water quality to the extent of reducing erosion in the tailwater drains, they would do little towards preventing material eroded from the field itself from entering the drains unless used in conjunction with contour furrowing, for example, or unless the sediment is collected. Sediment capture is discussed in the following section.

Tailwater Ponds--The water requirements for crops in the Valley generally range from about 50 to 65 percent of the water delivered to the farms as calculated from the water distribution summaries of the USBR. The remainder is lost to deep percolation and surface runoff, with a high proportion being the latter in many areas. In many cases, this water could be collected in a tailwater pond and pumped to the head of the field or to an adjacent field. Some sediment would also be pumped to the head of the field, while the remainder settling in the pond could be excavated and spread back on the land during the nonirrigation season.

The cost of installing a tailwater pond and recirculation system would depend on the field geometry and slope and whether the water was used on the same or an adjacent field. CH2M/Hill (1975) has estimated that for a 32 ha (80 acre) farm operation with average slopes of 5 percent, the total capital costs would be \$620 per irrigated ha (\$250 per acre). The annual cost of power, sediment removal and operation and maintenance is estimated to be \$30 per ha (\$12 per acre). Although the cost could be considerably less on flatter areas or where adjacent reuse is possible, the steeper lands are generally those most in need of remedial action. In addition, adjacent reuse is not usually possible for these steeper lands.

If a tailwater pond is installed only for the purpose of sediment collection, an outflow pipe is installed which allows the overflow to discharge to a drain. In this case, the capital cost has been estimated at \$50 per ha (\$20 per acre), with an annual maintenance cost of \$15 per ha (\$6 per acre). Data collected by CH2M/Hill (1975) indicates that 90 percent sediment removal can be obtained with a detention time of less than two hours.

The construction of tailwater ponds would improve water quality by removing sediment and absorbed phosphates. The irrigation districts would benefit from the lower cost of removing sediment from the drains. The short-term benefit to the individual farm operator might be limited to the recovery of some lost fertilizer. In the long term, the farmer would benefit if the soil saved from running off were spread back on the field.

If the tailwater were recirculated, the river would benefit from the reduced diversion requirement to the districts. However, in most districts the farmer would not benefit as the amount of water delivered is in excess of crop requirements. This water is delivered at a flat rate irrespective of the amount used until the allocated quantity is reached. An exception would be the Roza District which has a lower farm water allocation than the Valley average. In this district, there may be some cases where it could be cheaper to recirculate tailwater than to buy extra water. The Yakima-Tieton District also has a low water allocation to the farm of 2,973 m^3 (2.4 acre-feet) per share, with farmers having 0.4 (one) or 0.6 (one and one-half) shares per ha (acre). However, farmers in this district irrigate principally by sprinklers, with a corresponding low sediment yield.

Therefore, although this method may be useful in reducing sediment in return flows from farms, and is in fact being used in some parts of the Valley, from the farmers' point of view it only allows existing production levels to be maintained. For the capital outlay and annual costs, it allows no returns greater than those currently being experienced, although it does offer the potential for some savings in water charges, some recovery of lost fertilizer, and the long-term benefit of retaining topsoil.

Sprinkler Irrigation--A conversion by many of the farmers from surface methods to sprinkler irrigation systems could significantly reduce the wasteloads currently carried to the Yakima River by return flows. In contrast to many of the measures mentioned in the preceding sections, this conversion would also offer the potential of increased financial returns to the individual farm operator.

Sprinkler irrigation systems, properly designed, installed and operated, have many advantages. They permit quite uniform applications of water, the quantity of water applied can be effectively controlled, and the return flows from irrigation are reduced. Of particular importance to the Yakima Valley is their efficacy in erosion control when water is applied to land too steep for other irrigation methods. The ability of sprinkler irrigation systems to apply water uniformly to all soils allows surface runoff to be eliminated and deep percolation to be greatly reduced. Soil and nutrients are saved, so that costs of production of crops are significantly reduced. Benefits accrue both to farmers and to the region in general. At present, many thousands of dollars are spent annually by the irrigation districts to clean sediment from the drains, with additional funds spent to clean out plant growth which has been stimulated by nutrients in drainage water. These costs are paid by irrigation district members in the charges for their irrigation water. They could be greatly reduced by more efficient means of irrigation.

At present, over 100,000 acres of irrigated cropland in the Valley, or 20 percent, are irrigated by sprinklers, with the remainder irrigated by surface methods. The number of farmers who are investing in sprinkler systems is increasing, due to the economic advantages of these systems. Some are utilizing sprinklers for frost control. This use has increased as the cost of fuel for radiant heaters has risen. Farmers in the Yakima Valley cite reduced water use, lower labor requirements and increased crop yields as reasons for converting to sprinkler systems.

The lower labor requirements associated with sprinkler systems are particularly noticeable on the high intake soils and on steep or rolling lands where close water management is necessary with surface methods. Unfortunately, such management is not always found on farms with these soil characteristics. The pressure of other farm operations requires that irrigation be fitted in as incidental work that is carried out once or twice a day. When irrigation is via surface methods, a waste of water and in most cases topsoil is the consequence. Portable solid-set or permanent set systems are suited to such irrigation practices--labor requirements are very low and the systems lend themselves to automation for all water application purposes.

In areas with limited water supplies, such as the Roza District, the waste of water with surface irrigation methods is serious. Sprinkler systems are recommended because they allow small streams of water to be distributed over a larger area. Irrigation can be accomplished with other methods. Charges for "excess" water can be reduced and less water needs to be diverted from the river.

Nutrient losses by deep percolation are costly. They can be reduced by application of fertilizers at the time required by the plant, utilizing the sprinkler system. Water soluble fertilizers can be applied through the sprinklers with the timing and amount controlled to meet the needs of the plant. The ability to schedule fertilizer applications to plant needs rather than to cultural operations, as with surface irrigation methods, reduces the opportunity for leaching nutrients beyond the root zone. The amount of water applied can also be controlled to meet the needs of the crop, with light applications for seedlings and young plants. Traditionally, surface irrigation methods result in too much water being applied during seedling and plant emergence growth stages. This is the combined result of early season irrigation practices being similar to later irrigations when larger water applications are necessary, as well as inherent physical limitations in surface irrigation methods. However, much could be done to "tune up" such irrigation systems to allow higher early season irrigation application efficiencies. Water soluble herbicides and insecticides can also be applied through the sprinklers.

Land levelling is common in some parts of the Valley in association with relocation of sediment back to the head of the fields. This cost can be eliminated with sprinklers. Soils too shallow to be levelled properly for other methods can be irrigated safely with sprinklers. The land taken up by head-ditches, borders and tailwater drains can be brought back into production. The weed harbors in channels and drains can be eliminated. Wear on farm machinery due to crossing furrows is reduced and tillage is simplified.

Generally, one of the major obstacles to adoption of sprinkler irrigation is the high capital cost involved. The cost of converting the surface irrigation methods to sprinklers will vary markedly depending on the particular system adopted and the acreage irrigated. The following table gives typical capital and annual costs for different systems, based on installations in the Valley (Table 8).

The equipment cost is the original investment, amortized over the expected life of each system, at an interest rate of 4 percent. Labor and maintenance costs have been extracted from the CH2M/Hill (1975) report "Agricultural Return Flow Management in the State of Washington." Power costs are based on the pressure requirements of each system and the peak flow rates required to satisfy the demands of the crops to which each system is best adapted. Those power costs have been calculated from the rates supplied by Pacific Power and Light Company of Yakima. Each system generally operates within a limited pressure range at the sprinkler nozzle, and as most would be fed from the existing gravity water supply, the total pressure requirement may be reasonably estimated.

The investment requirements and annual costs of each system should be taken as indicative only. As each installation will vary according to size, crops grown, topography, and distance from source of water and power supply, costs may vary markedly and hence no attempt has been made at great refinement. Rather, the costs given would more likely represent a valley-wide average at today's prices. The difference in total annual costs between one system and another should not be taken as a comparison of the two systems under the same conditions. Rather, the total annual costs indicate the costs for a given

TABLE 9. COSTS OF ALTERNATIVE SPRINKLER IRRIGATION SYSTEMS

System	Investment Required ($/acre)	Annual Cost ($/acre)			
		Equipment	Labor & Maintenance	Power	Total
Handmove	250	20	35	10	65
Sideroll	250	22	27	8	57
Center-pivot	400	36	20	11	67
Portable Solid-set (non-automated)	800	59	15	15	89
Portable Solid-set (automated)	1,300	96	12	15	123
Permanent set (non-automated)	1,000	64	10	18	92
Permanent set (automated)	1,500	96	8	18	122

1 acre = 0.4047 hectares.

system for the type of crops for which it would most likely be adopted. Hand-move systems have been based upon their use for pasture; sideroll and center pivot sprinkler irrigation systems would be used for grain crops; and solid set and permanent sprinkler systems would be used on orchards.

Although power costs are only between 12 and 20 percent of the total annual costs of the various sprinkler systems, this cost and the likelihood of its increase are frequently quoted as reasons for a limitation on the future development of sprinkler irrigation in the Valley. If power costs do increase to the point of becoming a highly significant factor, consideration may have to be given to a system with many of the advantages of sprinkler irrigation, but with a lower power requirement--trickle irrigation.

Trickle Irrigation--Trickle or drip irrigation is a recently developed irrigation method and would appear to be particularly well adapted to the Yakima Valley. This method of irrigation has gained attention during recent years because of the potential for increasing yields, while decreasing water requirements and labor input. The concept behind trickle irrigation is to provide the plant with the optimal soil moisture environment continuously. This is accomplished by conducting water directly to individual plants, through laterals running along each row, instead of providing water to the entire field as with flood or sprinkler irrigation. The multitude of lateral lines are supplied by manifold lines which connect to the main line, which, in turn, connects to the water source. A control head is provided, generally at the water source, to regulate pressure and flow and to filter suspended solids from the water. A fertilizer injection system is often incorporated into the control head.

A wetted profile, the shape of which is largely dependent on soil characteristics, develops in the plant's root zone beneath the "trickler" or "emitter." Ideally, the area between trees and between tree rows is dry and receives moisture only from incidental rainfall. Trickle irrigation saves water because only the plant's root zone is supplied with water and little water should be lost to deep percolation or evaporation under proper management. The only irrigation return flow is that due to a leaching fraction which may be necessary to prevent excessive salt buildup in the root zone. There is no surface runoff and very little nonbeneficial consumptive use of water by weeds. Water savings are effected through the ease with which the correct amount of water is accurately applied.

The Washington State University Experiment Farm at Prosser is successfully growing orchard crops with trickle irrigation using only a fraction of the water being used for sprinkler irrigation. This low water requirement reduces pipe size and the use of power. In some other installations in the Yakima Valley, the pressure requirement is being provided totally by gravity.

Crop response to trickle irrigation in the Valley appears to be somewhat superior than to other systems of irrigation, particularly with new plantings. Fruit growers have been pleased with the earlier maturity of trees. This is probably a result of the absence of moisture stress, which occurs with other irrigation methods in the water-short districts. A well-managed trickle system will result in effective soil aeration, provision of sufficient available nutrients by fertilizer injected into the water and a nearly constant, low tension soil moisture condition. By minimizing the wetting of the soil surface and plant foliage, trickle irrigation reduces the development of many insect, disease and fungus problems. In addition, the efficiency of pesticide sprays is increased.

Yakima Valley farmers first began using trickle irrigation during the early years of large-scale commercial development. The earliest systems in the Valley were installed during 1971. Some of the innovative farmers jumped at the chance to try what seemed to be a low-labor, low-cost irrigation system. Many unproven emitters were available, with microtubes most frequently used. Farmer-installed systems were sold for as little as $620 per ha ($150 per acre). Sand filters were often underdesigned and therefore required frequent backflushing. Water quality factors other than suspended solids were not adequately examined. Farmers expected cheap, yet effective, miracles. These factors resulted in many abandoned systems and negative feelings about trickle irrigation.

Where trickle irrigation systems have been abandoned, the chief reason cited is the constant blocking of emitters. The most common cause of clogging has been particles of sand and silt, organic growth and chemical precipitation in the microtube emitters. Filtration of the irrigation water is the best defense against these occurrences, together with chemical additives where necessary.

At the Washington State University Experiment Farm at Prosser, screens, Laval separators and graduated sand filters are used to filter the irrigation water which contains large amounts of suspended solids. Prosser is located at the southern end of the Yakima Valley where the quality of irrigation water supplies is poorest. The Laval separators are backflushed continuously by a small flow and the sand filters are automatically backflushed every half hour during system operation. This is accomplished by a clock which starts an electric motor to which cam-operated valves are linked. No major problems with filtration or emitter performance have been encountered.

Other operators have also overcome the problem of emitter blockage by ensuring adequate filtering, as well as replacing microtube emitters by more reliable types. At least one grower is enjoying success with mist emitters or "foggers." These comparatively inexpensive emitters spray water vertically upward and water reaches the ground as a mist covering an area a couple of meters across. If plugging should occur, the emitters can readily be cleaned by unscrewing the cap containing the orifice and allowing a large quantity of water to flow.

Systems which are operating properly (or at least adequately) do not insure proper application of water, however. There are instances where orchards are irrigated continuously for several weeks instead of being irrigated for several hours every day of the season. This negates many of the advantages associated with trickle irrigation.

In order to overcome the negativism associated with trickle irrigation, future systems must be well designed, relatively maintenance free and properly managed. This requires the service of competent engineers, with a knowledge of the various trickle emitters and filtration systems presently available, and with the ability to provide a follow-up management service. In fact, some demonstration on farmers' fields will be initially required (which incorporate the principles stated above) in order to gain farmer acceptance of trickle irrigation. Farmers who desire a system with little labor input should consider automatic backflushing filters, fertilizer injection and soil moisture detecting controllers. Some emitter plugging due to human or water quality factors should be anticipated, and a systematic approach used to correct these problems as they develop.

For irrigation of widely spaced crops (e.g., fruit trees), the cost of a correctly designed trickle irrigation system is relatively low in comparison to that for other solid set of permanent irrigation systems. In orchards, the cost of a trickle irrigation system may be lower than that for a solid set or permanent sprinkler system having the same level of automation. In addition, where clogging is not a problem and emitter line maintenance is minimal, operation and maintenance costs of the trickle irrigation system are usually quite low. However, in plantings of row crops or vines, where the average distance between emitter lines must be less than 10 feet, the cost of trickle irrigation is relatively high (Keller and Karmeli, 1975).

For the purpose of a cost analysis for typical trickle irrigation installations in the Yakima Valley, preliminary designs were prepared for square fields of 6, 12 and 24 hectares (15, 30 and 60 acres) for both manual and automated systems. The costs associated with these designs are much higher than previously experienced in the Valley as the systems have been designed to provide a high degree of reliability and to correctly supply crop water needs. The water supply has been assumed to be located at the top of the field, with a field slope of 5 percent. The commonly accepted apple tree spacing of 3.7 by 5.5 m (12 by 18 feet) was used, resulting in 500 trees per hectare (200 per acre).

Screen filters were utilized for both the manual and automated systems. A pressure differential across the screen causes the filter for the automated system to backflush as necessary. The value used for total suspended solids was 400 mg/l maximum.

The transpiration peak for mature apple trees was considered to be 6.4 mm/day (0.25 inches/day) under trickle irrigation. After considering such factors as emission uniformity and the ratio of transpiration to application, this means that each mature tree must be supplied with approximately 150 liters (40 gallons) of water per day during the period of peak transpiration.

The systems were designed to operate for 15 hours per day (3 irrigation sets) and 20 hours per day (4 irrigation sets) for the manual and automated designs, respectively. Figure 10 shows the layout of the 6 hectare manual system. Layout of the 6 hectare automated system is identical except it has 4 irrigation sets. Layout of the 12-24 hectare sets differ only in dimensions except for additional lateral manifolds on the 24 hectare systems.

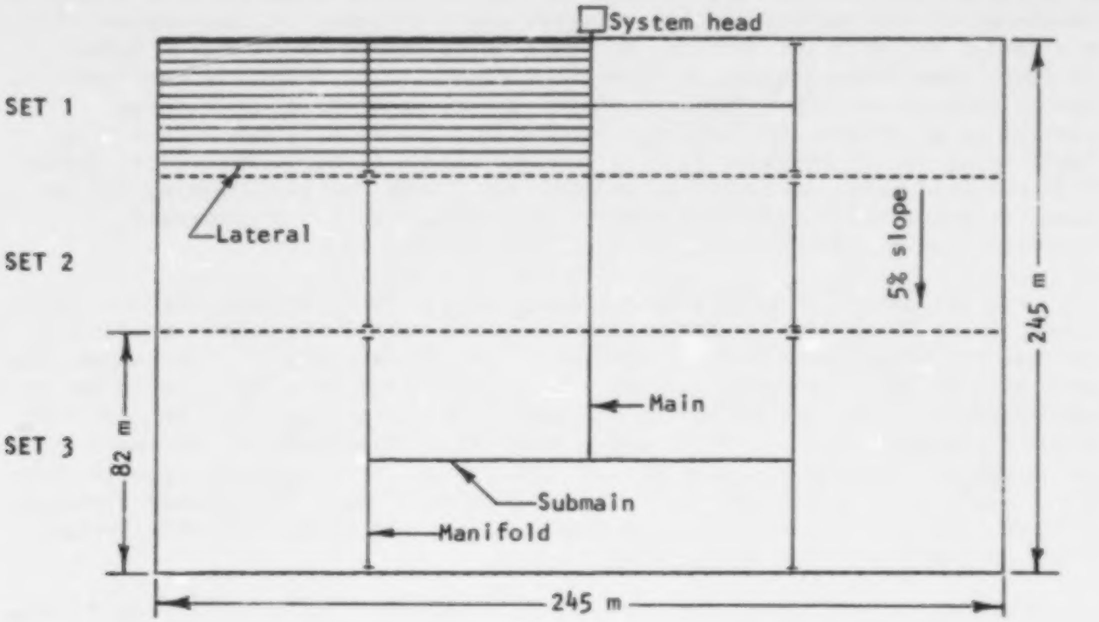


Figure 10. Layout of the 6 hectare trickle irrigation system showing various components of the distribution network.

An initial investment cost analysis for each system as described is presented in Table 10. Note that the per hectare cost varies from a low of \$2,814 for a 24 hectare manual system to a high of \$3,260 for a 12 hectare automated system. The per hectare cost of the 12 hectare automated system is higher than the unit cost of a 6 hectare automated system because of the necessity of more PVC piping. PVC is substantially more expensive than polyethylene pipe, but is necessary for large pipe diameter requirements.

Irrigation Scheduling--Irrigation scheduling programs have been developed for many areas, including southern and eastern Washington. The USBR has developed irrigation scheduling services for some of its projects, developed with a fivefold objective to:

1. Increase crop yields and quality.

2. Reduce fertilizer losses.

3. Reduce the amount of unnecessary water and labor inputs to farming.

TABLE 10. INITIAL INVESTMENT COST ANALYSIS FOR TRICKLE IRRIGATION ON AN ORCHARD CROP ON A 3.7 BY 5.5 METER SPACING

DESCRIPTION	6 Hectare System		12 Hectare System		24 Hectare System	
	Automated	Manual	Automated	Manual	Automated	Manual
MATERIALS						
System head						
Pump	769	871	990	1,036	1,174	1,391
Screen filter	1,689	1,184	2,598	1,184	3,186	1,772
Flow meter	265	265	428	428	483	483
Pressure gauges	23	23	23	23	23	23
Fertilizer injector	187	187	187	187	187	187
Controller	600	--	600	--	600	--
Miscellaneous (5% of above)	176	127	241	143	283	193
Subtotal	$ 3,700	$ 2,657	$ 5,067	$ 3,001	$ 5,936	$ 4,049
Distribution system						
PVC pipe	1,523	3,288	8,723	7,327	20,025	16,092
Polyethylene pipe	2,024	1,826	3,437	3,437	7,273	7,273
Pipe fittings	540	540	1,060	1,060	2,160	2,160
Emitters	6,900	6,900	13,800	13,800	27,600	27,600
Tensiometers	59	59	107	107	204	204
Pressure regulators	520	390	1,039	779	2,078	1,559
Manual valves	20	40	50	200	60	240
Solenoid valves	100	--	248	--	300	--
Electrical wire	227	--	321	--	203	--
Miscellaneous (5% of above)	596	652	1,438	1,336	2,996	2,756
Subtotal	$12,509	$13,695	$30,224	$28,046	$62,899	$57,884
LABOR						
Head installation[1]	1,275	850	1,700	1,275	1,700	1,275
Main and submain installation (buried)[2]	600	540	1,253	1,241	3,190	2,575
Emitter lateral installation (on surface)[3]	400	400	875	875	1,750	1,750
TOTAL COST	$18,484	$18,142	$39,119	$34,438	$75,475	$67,533
PER HECTARE COST	$ 3,080	$ 3,024	$ 3,260	$ 2,870	$ 3,145	$ 2,814

[1] At an $8.50/hour rate.

[2] At $0.50/meter for the 6 hectare system, and $0.82/meter for the 12- and 24-acre systems.

[3] At a $2.50/hour rate.

4. Reduce drainage problems.

5. Improve the quality of return flows.

All of these objectives are relevant to the Yakima Valley. From the individual farm operator's point of view, the objectives may be summarized as: applying the optimum amounts of water at the optimum time intervals to obtain the maximum economic returns.

Long before the advent of digital computers, climatological monitors or instantaneous communication systems, successful irrigation farmers were scheduling irrigations based on, for example, the appearance of the crop or the feel of the soil. However, the fallibility of experience and judgment has been demonstrated throughout the world as overapplication of water has led to yield reductions due to fertilizer leaching, poor soil aeration and plant diseases. In addition, such inefficient irrigation practices have caused regional water quality problems, mosquito nuisances, public health problems, and local property damage due to waterlogging of soils and seepage of water into basements of homes and businesses.

The relative ease with which irrigation can be programmed for digital computers has allowed irrigation scheduling services to be provided to a large number of irrigators by a single facility. Modern districtwide irrigation scheduling programs consist of six primary steps (Figure 11) (Skogerboe, Walker, Taylor, and Bennett, 1974).

First, an inventory of the soil and crop characteristics for each field is made to gain an understanding of the essential requirements for efficient irrigation. A calculation of the water needs of the growing crops is then made, specifically at what rates are the crops and soil surfaces utilizing water from the soil moisture reservoir. Such estimates are generally based on well tested empirical techniques, rather than actual measurements, because of convenience and the established reliability of the computational procedures. The next aspect of irrigation scheduling is to determine the availability of moisture in the root zone for meeting crop needs between irrigations. This step is accomplished by initially sampling the soil profile to measure the available soil moisture storage and then periodically sampling to reassess the available moisture and update the consumptive use estimates. Upon determining the amount of soil moisture available, the interval between irrigations is projected. In addition, by knowing the soil and irrigation system characteristics, the amount of water to be applied (as well as the means to accomplish the suggested application) can be determined. Finally, the results of the previous steps must be delivered to the irrigator in order to implement the suggestions. Also, proper implementation is highly dependent upon flow measurements being available to the farmer so that he knows "what he is managing." This program is subsequently repeated throughout an irrigation season.

This service offers the potential to improve water quantity and quality in the Yakima River while at the same time enhancing returns to the farmer. The cost varies according to the extent of service offered, but is usually in the range of \$2.70 to \$12.50 per ha (\$1.50 to \$5.00 per acre). Of course,

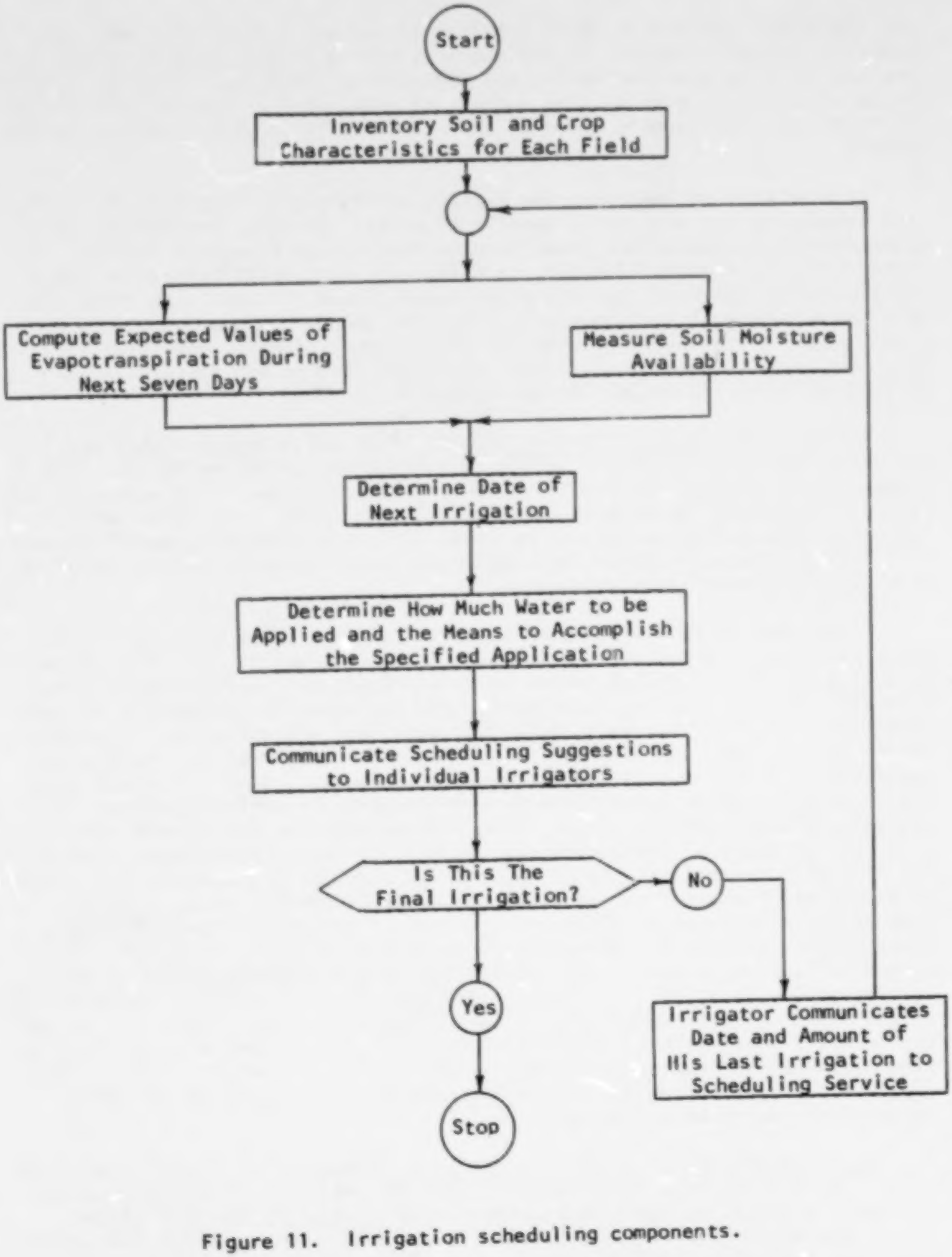

Start
Inventory Soil and Crop Characteristics for Each Field
Compute Expected Values of Evapotranspiration During Next Seven Days
Measure Soil Moisture Availability
Determine Date of Next Irrigation
Determine How Much Water to be Applied and the Means to Accomplish the Specified Application
Communicate Scheduling Suggestions to Individual Irrigators
Is This The Final Irrigation?
No
Yes
Stop
Irrigator Communicates Date and Amount of His Last Irrigation to Scheduling Service

Figure 11. Irrigation scheduling components.

many individual irrigators could schedule irrigation applications more precisely at virtually no cost if the required knowledge were made available to them and provided they had sufficient time during their busy schedule to make the necessary measurements. The success of commercial irrigation scheduling companies has been largely based on their ability to provide a service to the farmers.

As a measure of improving the quality of irrigation return flows, irrigation scheduling can only be of benefit if either, or both, the surface (tailwater runoff) or subsurface (deep percolation) return flows are reduced. There is little documented proof, to date, that commercial irrigation scheduling services are reducing irrigation return flows. There is no doubt that this can be accomplished; however, irrigation scheduling must result in modified irrigation practices in order to reduce return flows. Modifying irrigation practices is the most important aspect of "tuning up" the irrigation system, which is the subject of the following section.

Improving Existing Irrigation Methods--Much can be accomplished by analyzing existing irrigation methods and practices in Yakima Valley. The primary difficulty is the availability of technically qualified personnel and funding for making the necessary measurement on a sufficient number of farm fields so that proper advice can be given to farmers regarding modifications to existing irrigation practices that would result in water quality benefits, as well as increased crop production.

Field measurements are needed on farm fields in order to establish the quantity, quality and timing of farm irrigation deliveries, the flow characteristics of the irrigation method being employed, consumptive use by crops, tailwater runoff, leaching requirement, and the quantity and quality of deep percolation losses. For each field that such data are collected, recommendations can be made regarding modified irrigation practices that would more beneficially utilize water supplies and fertilizers. Also, this field data will show constraints being faced by the irrigator in achieving higher irrigation application efficiencies. Then, recommendations can be made regarding a variety of physical improvements which could be made to eliminate some or all of these constraints. These recommended physical improvements can consist of simple modifications to the existing irrigation method (e.g., concrete head ditch, employment of different sizes of siphon tubes, flow measurement structure(s), gated pipe, automated concrete head ditches, etc.); conversion to new irrigation methods (e.g., converting from furrow irrigation to sprinkler irrigation or trickle irrigation); or could involve physical improvements in the water delivery subsystem, in particular, the lateral(s) (e.g., lining the lateral, placing the irrigation water supply in a pipeline, constructing flow measurement structures, improved water control structures, etc.). Also, the employment of irrigation scheduling in conjunction with any of these improvements would be highly beneficial.

Modification of Fertilizer Practices--As discussed in preceding sections, two of the most serious contaminants of the Yakima River are phosphorus and nitrogen, of which agriculture contributes 15 percent of the load of the former and 66 percent of the latter. Nitrate levels in the river near Benton City have increased sixfold in the period 1953 to 1974 (0.2 to 1.2 mg/l)

(CH2M/Hill, 1975). This corresponds to the increasing use of fertilizer in recent years. The effects of fertilizer residuals on water quality have been discussed in a previous section. The effects of overfertilization on farm economy and the benefits of a reduction in fertilizer use have been described aptly by CH2M/Hill (1975) as follows:

> Increased use of fertilizers in recent years has led to significant increases in crop productivity. However, plant nutrients, either native or added by commercial fertilizers, are of no value to the crops if they are washed or leached from the soil; they can then cause serious water quality problems....
>
> Fertilizer application theoretically can be added to the soil to meet the exact requirements of the individual crops. If fertilizer application could be accomplished more efficiently, reduction in applied amounts could probably be realized. Among evaluations that can be made is the practical use of soil analyses to determine the native nutrient constituents so that only the necessary fertilizer is applied. This can lead to more efficient use of various fertilizer types.
>
> In addition, improved placement of fertilizers should be evaluated. This can often be effected through mechanical means or certain water application methods. Only one example of this concept is using a type of drip or trickle irrigation developed in Israel. Using this method, precise amounts of nutrients are applied directly to the root zone of the crop.
>
> An improved or more efficient application of fertilizers must be evaluated in conjunction with improved or more efficient methods of water application and soil management. When this is done, significant reductions in the amount of salts reaching the water bodies can be realized.
>
> To optimize the benefits to farm operators and minimize the effect of fertilizers on water quality, three considerations are important:
>
> 1. The timing of fertilizers reaching the plant roots should be such that optimum levels of production can be obtained;
> 2. The correct amount of fertilizers must be available to obtain best production (overapplications, as well as underapplications, can affect crop production); and
> 3. Overapplication of either fertilizers or water can cause leaching of fertilizers below the root zone, where it will enter the ground water or streams by subsurface flows.

Modification of fertilizer practices can be accomplished more frequently in conjunction with improved on-farm water management practices. In fact, incorporating soils analyses for fertilizer recommendations into an irrigation scheduling service would be highly beneficial to the farmer. Thus, "tuning up" the on-farm irrigation practices, along with irrigation scheduling, would directly result in better utilization of fertilizer and consequent reductions in the fertilizer residuals which eventually return to the Yakima River. The combination of "tuning up" on-farm irrigation practices, modified fertilizer practices and irrigation scheduling would yield significant benefits to the farmer in increased crop production as well as improved quality of irrigation return flows.

Treatment--

Grassed Return Flow Ditches--Grassed return flow ditches have been proposed to improve water quality by reducing erosion and permitting nutrient uptake by aquatic plants. A comparison of CH2M/Hill (1975) of data from two sampling stations indicated that the station with a grassed ditch above it had a proportionately lower suspended sediment yield than at the other location.

To reduce erosion in the drains would require that the grade be flattened and drop structures provided. A larger cross-sectional area of flow would therefore be required, making this method applicable only to the shallow drains. The capital cost has been estimated by CH2M/Hill (1975) as $5,000 per kilometer ($8,000 per mile). To this must be added the annual cost of maintenance, any necessary reseeding and desilting of the drains. A more feasible approach might be to maintain higher velocities, not high enough to cause drain erosion, but sufficiently high to retain the sediment in suspension, allowing it to be carried to a treatment pond. From this centralized location, sediment could be removed more economically than from many kilometers of drain.

Treatment Ponds--Ponding of drain flows might be considered for some of the larger drains in the Valley having high sediment and/or nutrient levels, such as South Drain, Sulphur Creek, Granger Drain, and Spring Creek. Treatment ponds could remove sediment, nitrates and phosphates. According to CH2M/Hill (1975), the removal of sediment will require only about two hours detention time for 90 percent removal, whereas 90 percent removal of nitrates and phosphates may require 15 days or longer. Nitrates and phosphates can be removed effectively through the growth of algal organisms but the organisms must be harvested for the process to be effective. Because of the difficulty and expense of building treatment ponds in other drains, CH2M/Hill (1975) considers that the only area where this method might be feasible would be on Sulphur Creek. Here, natural ponds already exist and land costs would be fairly low. The total capital cost has been estimated to be $240,000 and annual operation and maintenance costs $75,000. The expected benefit is that suspended solids in this drain would be 90 percent removed, total phosphate would be 60 percent removed and total nitrogen would be 40 percent removed.

Advanced Treatment Systems--Advanced treatment systems could only be considered for the flows of Sulphur Creek because of physical and financial limitations. Processes relevant to irrigation return flow quality include the addition of coagulants for sediment removal, algal stripping and bacterial denitrification for nitrogen removal. For the flows and constituents recorded in Sulphur Creek, CH2M/Hill (1975) gives the following tabulation of expected costs for various removal procedures.

Process	Removal Efficiency	Capital Cost, $	Annual Cost, $
Chemical Coagulation	99% sediment	10,200,000	1,742,000
Algal Stripping	90% nitrate	3,600,000	30,000
Bacterial Denitrification	90% nitrate	1,300,000	75,000

The costs of these alternatives would make advanced treatment difficult to justify in comparison to other alternatives.

It is obvious from the above that quite a variety of technical alternatives become feasible through an assessment of potential solutions. Equally important, however, is the team's legal and socio-economic evaluation of proposed solutions.

Economic Evaluation

Water Rental Market--

The work of Pfeiffer and Whittlesey (1975) at Washington State University is useful in determining the potential effect of a water rental market on the water quality in the Yakima River. A linear program which modeled farmer responses to alternative policies was linked with a hydrologic and water quality model of the Yakima River. The research shows the effect of different pricing and regulatory policies on the quality of water in the Yakima River. Although the establishment of a water rental market was not one of the policies considered, the information generated in this research can be applied to an analysis of such a market. Table 11 displays the relevant data.

As indicated earlier, sediment is considered the major water pollution problem in the area. Because of hydrologic complexities, it was very difficult to model actual levels of sedimentation in the Yakima River. Therefore, measures of sediment loss per irrigated acre were used as indicators of levels of sedimentation in the Yakima River.

In order to determine the effect of market establishment on sedimentation in the Yakima River, supply and demand curves for water under the current system must first be derived. The demand curve, D_L in Figure 12, is derived by plotting the response of water right holders to alternative water tax levels as developed by Pfeiffer and Whittlesey. At low tax levels, the irrigators demand more water than they do as tax levels increase. Plotting the quantity demanded at each price yields a demand curve for water. The demand curve measures the marginal value product of water to irrigators of the current 453,000 acres (183,329 ha). It indicates the decreasing value of the product produced by each additional unit of water.

The supply curve, S_L, reflects the fact that water is supplied at the average conveyance cost of $5.00 per acre-foot ($4.05 per cubic meter), up to the total available annual water supply of 2,393,000 acre-feet (2,953 million cubic meters). Note that water right holders are currently using the entire flow of thefully appropriated river.

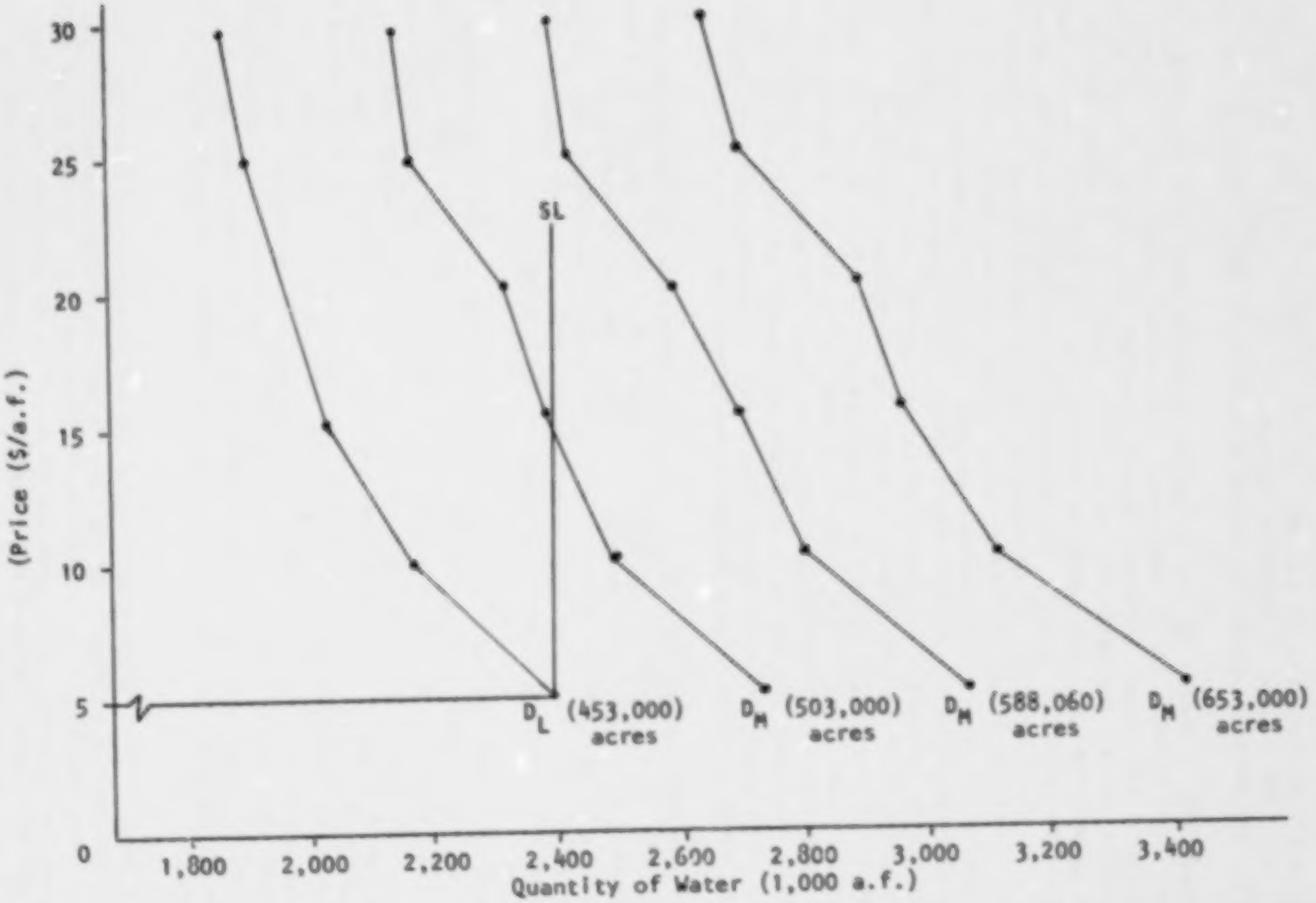
Also shown in Figure 12 are three potential market demand curves under differing assumptions of irrigable acreage (hectares) held by non-right

TABLE 11. RESULTS OF DIFFERENT WATER PRICES

	Market Price -- Water					
	Present Cost (Conveyance) $5.00	$10.00	$15.00	$20.00	$25.00	$30.00
Water Applied (1,000 ac.-ft.)	2,393	2,393	2,393	2,393	2,393	2,393
Water Applied (ac.-ft./acre)	5.28	4.77	4.53	4.44	4.10	4.07
Acres Irrigated (1,000 acres)	453	502	528	539	584	588
Sediment Loss (T/acre)	1.74	1.31	1.00	0.91	0.35	0.32
Total Sediment Loss (1,000 T)	788	658	528	490	204	188
Per Acre Net Crop Income (R)	236	216	228	263	303	291
Net Crop Income ($1,000)	106,908	108,432	120,384	141,757	176,952	170,817

1 acre-foot = 1,234 cubic meters.
1 ton = 907.185 kilograms.
1 acre = 0.4047 hectares.

SOURCE: Derived from Pfeiffer and Whittlesey, page 37.



1 acre-foot = 1,234 cubic meters.
1 acre = 0.4047 hectares.

SOURCE: Pfeiffer and Whittlesey.

Figure 12. Legal allocation of water.

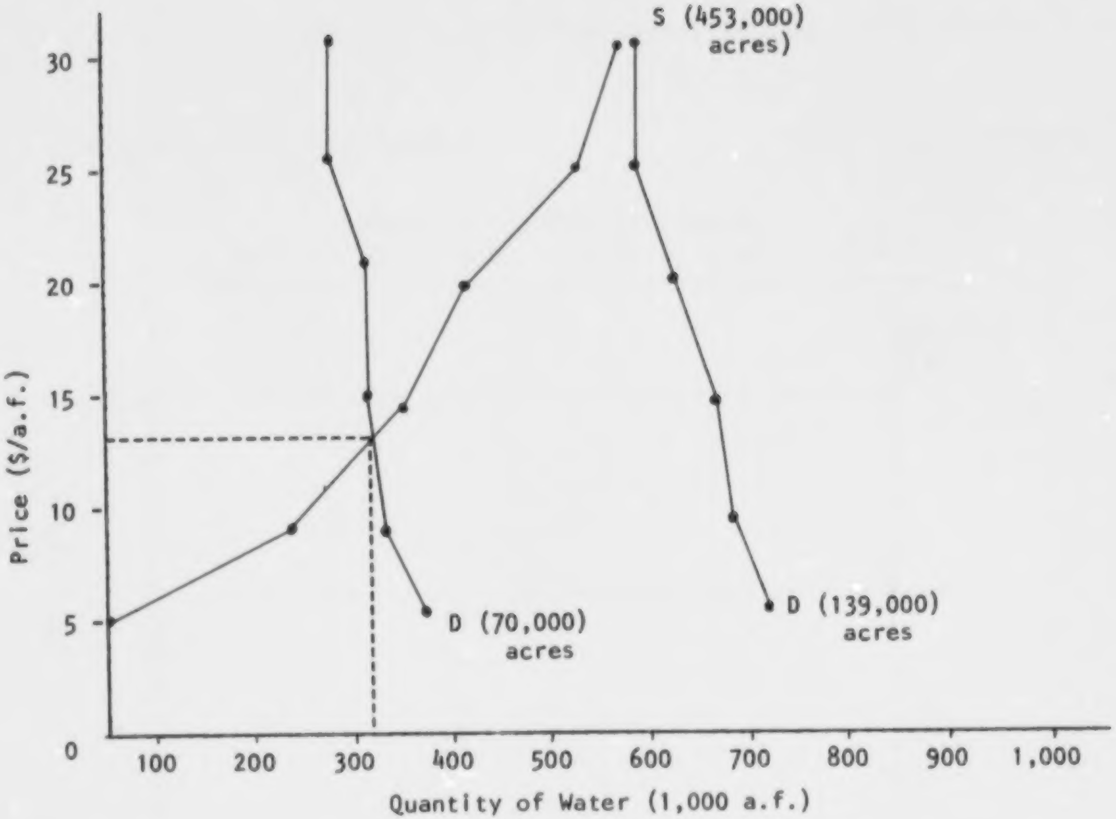
holders. D_M (523,000) reflects the demand of water right holders and non-right holders, assuming 70,000 additional irrigable acres. D_M (653,000) assumes 200,000 (80,940) additional acres (hectares), and D_M (588,000) assumes a median estimate of 135,000 (54,634.5) additional irrigable acres (hectares). The current allocation system responds, however, only to the demand of the water right holders with 453,000 (183,329.1 hectares) acres.

Assume that a rental market for water is introduced into the area, so that non-right holders could rent water from current water right holders for irrigation of additional acreage. Assume further that rental is restricted to transfers within the agricultural sector. Each unit of water held by current water right holders could be used to yield a return in agricultural production or could be rented. The opportunity to receive rent for each unit of water is the foundation of the upward sloping supply curve in Figure 13. Its exact location is determined by calculating how much water will be placed on the market by water right holders at each price. This amount would be the same as the amount by which they would reduce their diversions if water was taxed at dollar amounts, corresponding to each price, and so it can be derived from Pfeiffer and Whittlesey's data. These points, indicated by X's, are plotted as the supply curve for rental water. A plotting of the quantity of water demanded by non-right holders at each price yields a demand curve for two of the estimates of additional irrigable land. In order to avoid overstatement, the remaining analysis will use the lowest estimate of 70,000 (28,329) additional irrigable acres (hectares) in determination of the effect of establishing a water rental market on water quality.

The important information to be gained by reference to the supply and demand curves is the equilibrium price of water that would result if a water rental market was created in the Yakima Valley. As can be seen from Figure 13, the equilibrium price is about \$14.00 per acre-foot (\$11.34 per thousand m^3). At this price, approximately 320,000 acre-feet (395×10^6 cubic meters) of water would be rented from water right holders.

Figure 14 shows an individual water right holder's supply and demand for water. The individual response to the creation of a water rental market can be seen from this figure. At present, the irrigator is paying approximately \$5.00 per acre-foot (\$4.05 perthousand m^3) for irrigation water and is allocated an average of 5.28 acre-feet per acre, as reflected in the legal supply curve, S_L. His initial demand curve, d_L, reflects the marginal value product of water in agricultural production. Creation of the opportunity to rent water causes his demand curve, d_R, to become horizontal at the \$14.00 (\$11.34 per thousand m^3) rental price. He will reduce the water application on his land to 4.575 acre-feet (5,646 cubic meters) per acre and rent the remaining 0.705 acre feet per acre (2,150 cubic meters per hectare) to non-right holders.

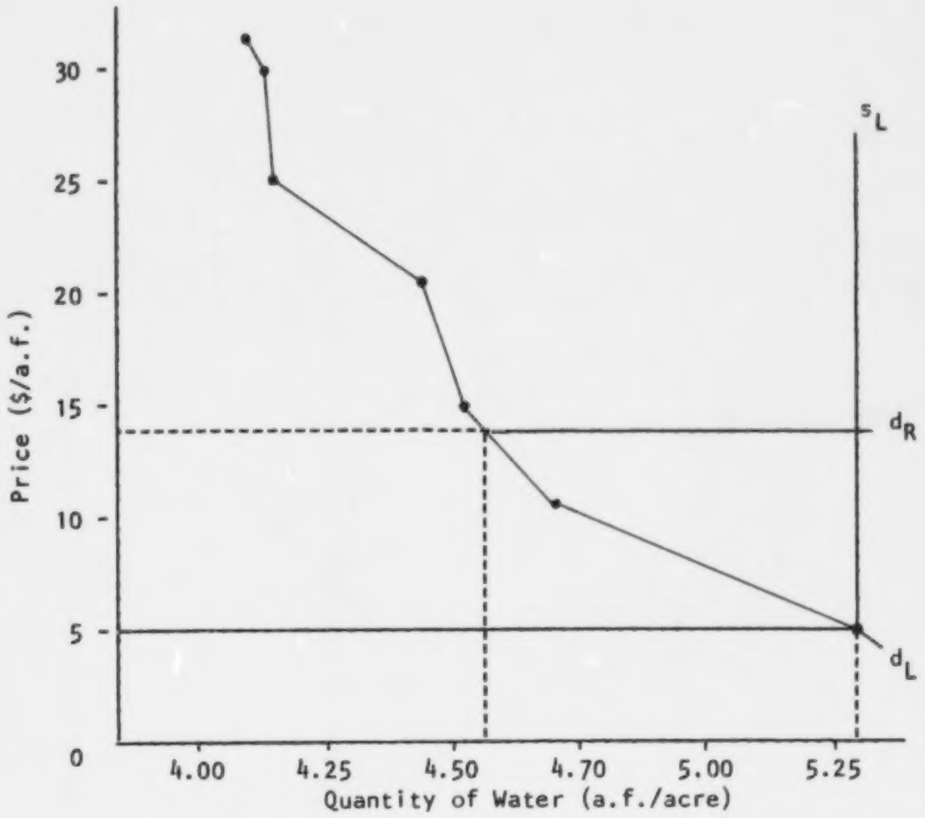
The situation of the non-right holder is illustrated in Figure 15. His demand is assumed to be identical to farmers who currently are water right holders. Those who begin irrigation operations may face initial fixed costs which cause the marginal value produce of water to be somewhat lower than that of current users. After the initial period, however, these will be treated as sunk costs and not included in the demand function. At present,



1 acre-foot = 1,234 cubic meters.

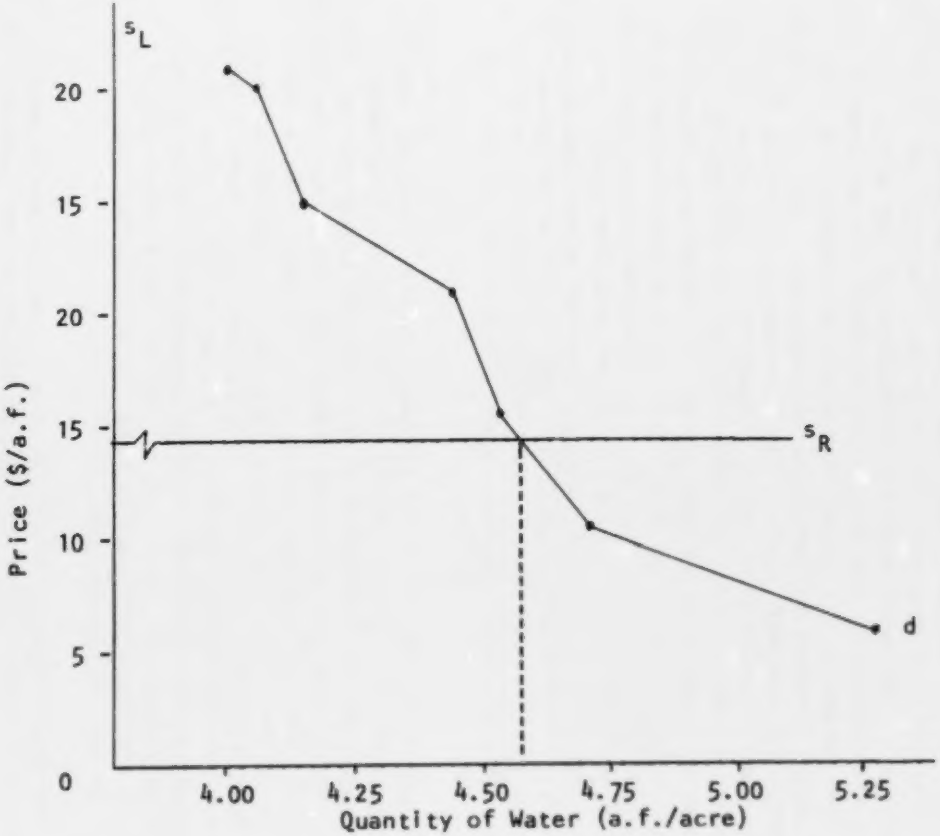
1 acre = 0.4047 hectares.

Figure 13. Water rental market.



1 acre-foot = 1,234 cubic meters. 1 acre = 0.4047 hectares.

Figure 14. Supply and demand for water right holders.



1 acre-foot = 1,234 cubic meters.

1 acre = 0.4047 hectares.

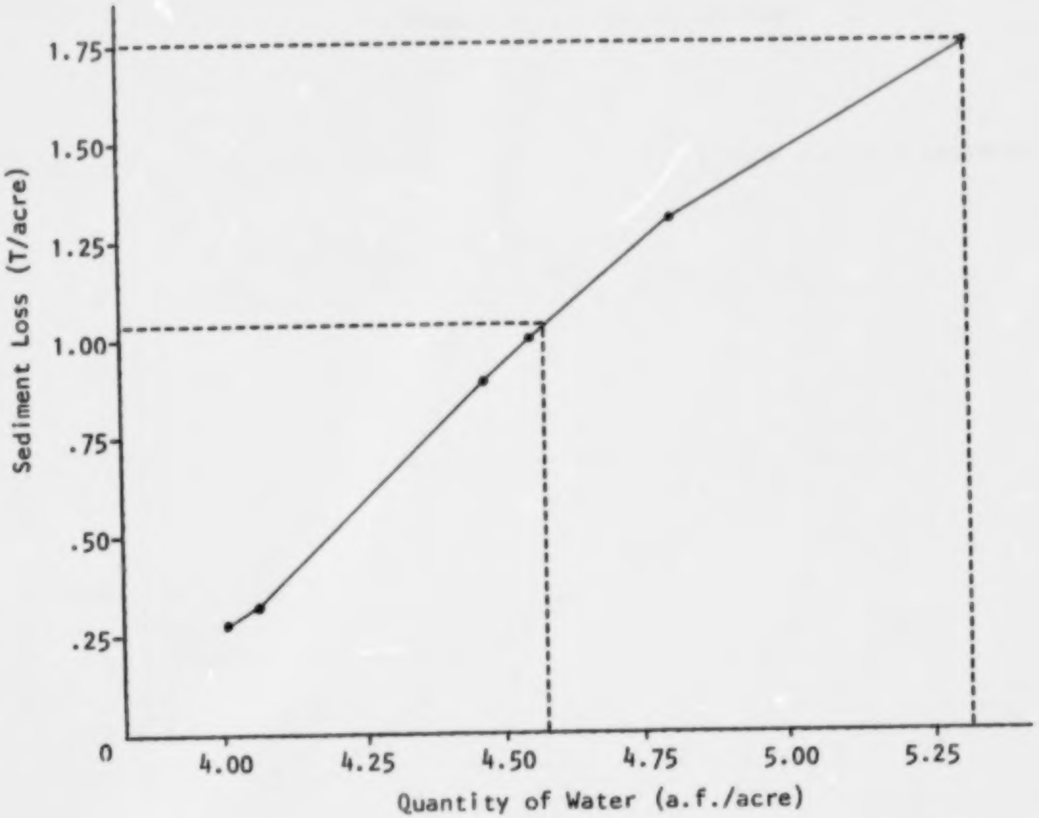
Figure 15. Supply and demand for right and nonright holders.

the non-right holder has no supply of water, so his supply curve, s_L, follows the Y-axis. Creation of a water rental market generates a supply curve, horizontal at the $14.00 ($11.34 per thousand m^3) rental price. At that price, each non-right holder will rent 4.575 acre-feet of water per acre (5,646 cubic meters).

Pfeiffer and Whittlesey's hydrologic and water quality model indicates the changes in sediment loss that will accompany changes in water application. rates. This information is plotted in Figure 16. A reduction of 0.705 acre-feet per acre (2,150 cubic meters per hectare) has a marked effect on the sediment lost per irrigated acre (hectare). Figure 16 illustrates this fact, showing a reduction in sediment loss from 1.74 tons per acre (3.9 ton (metric) per hectare) to 1.04 tons per acre (2.33 ton (metric) per hectare) a 40 percent reduction. The water quality improvement of the market creation would be partially offset by the fact that, although the sediment loss in tons per acre from currently irrigated land would be reduced, the total acreage irrigated under a market system would be increased. The increase is calculated by determining how much land could be irrigated, with the fixed water supply at each water application rate. Figure 17 illustrates the increase in total acres (hectares) from 453,000 (183,329) to 523,000 (211,658), that accompanies the decrease in water applied per irrigated acre (hectare). The trends depicted in both Figure 16 and Figure 17 are then incorporated into Figure 18. This figure illustrates the total sediment loss that accompanies each level of water application per irrigated acre (hectare). Total sediment lost under the current legal allocation of water equals approximately 788,000 tons (714,861,780 kilograms) (see Figure 18). The establishment of a water rental market would diminish the total sediment lost to a level of about 544,000 tons (493,508,640 kilograms), a reduction of 31 percent (see Figure 18).

Two factors suggest that the effect of the water market on water quality is actually understated in the present analysis. Firstly, it is probable that a higher percentage of the 788,000 tons (714,861,780 kilograms) of sediment currently lost from farms would actually reach the river than the 544,000 tons (493,508,640 kilograms) of sediment which would be lost under a market system. This is due to the higher velocity of the larger quantity of water which is carrying that sediment. Secondly, Pfeiffer and Whittlesey's model is based on current water application methods. It seems likely that if a water market were created and the farmer thereby experienced higher prices for water, he would be induced to invest in capital or labor which would cause the water to be used more efficiently, and thereby further reduce the total sediment loss on his irrigated acreage.

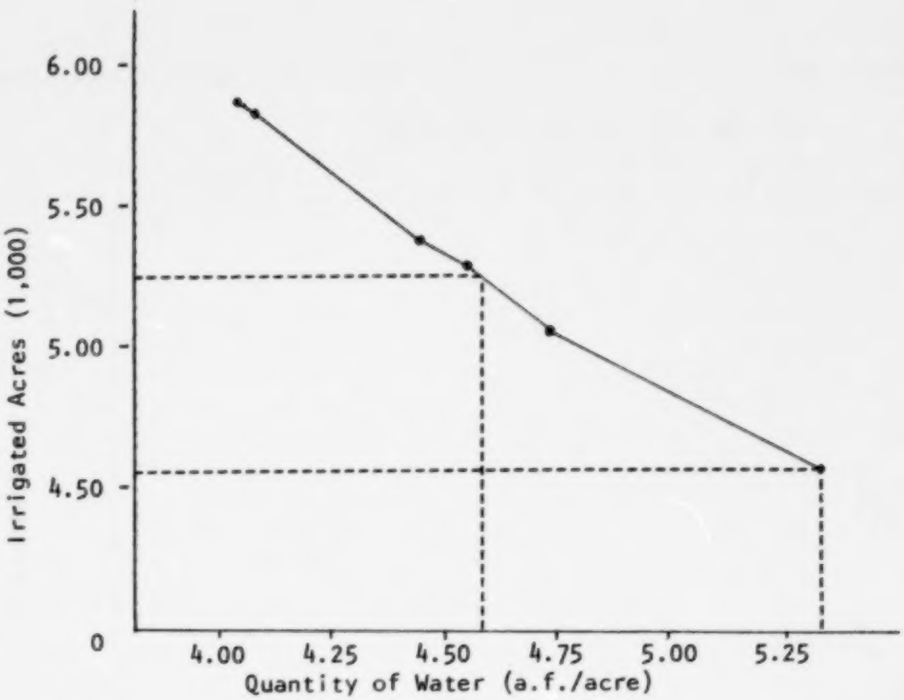
This analysis indicates that the creation of a market for water would bring about at least a 31 percent decrease in sedimentation and turbidity of the Yakima River. At current sediment loss levels of 788,000 tons, maximum turbidity averages 15 JTU in reaches of the stream with a 10 JTU standard, and 7 JTU in reaches with a 5 JTU standard. Even if the 31 percent reduction in sediment loss from farms only reduced sediment levels in the stream by 31 percent, this change would be sufficient to bring the average turbidity into compliance with Washington State Water quality standards, as illustrated in



1 acre-foot = 1,234 cubic meters.

1 acre = 0.4047 hectares.

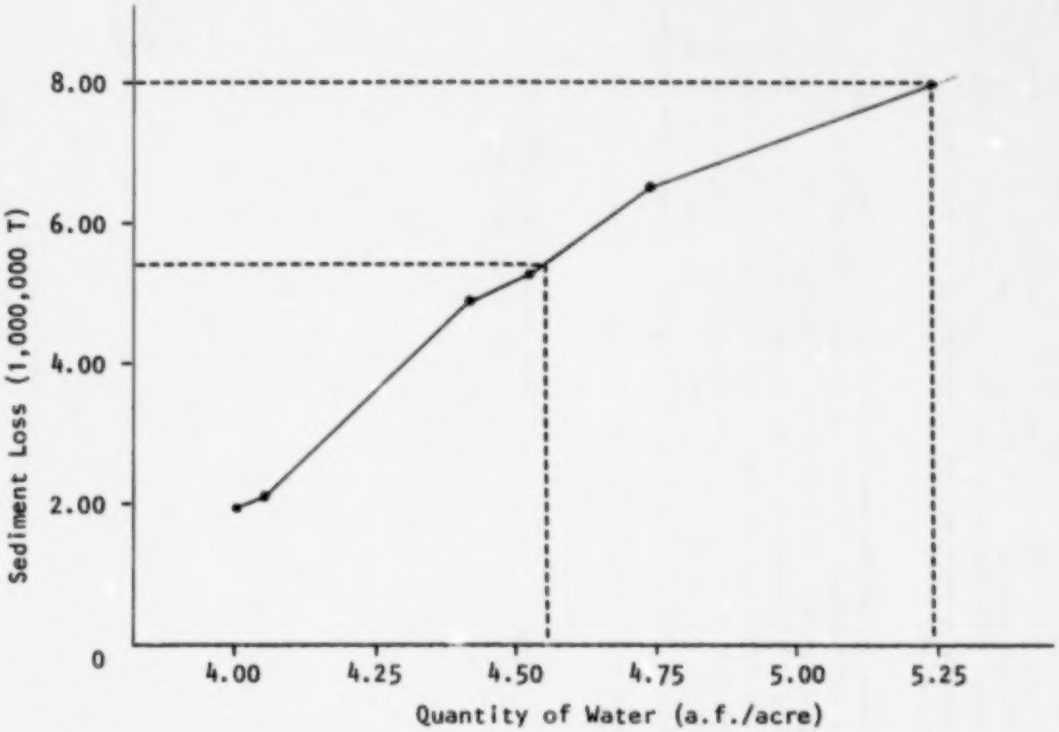
Figure 16. Per acre sediment loss.



1 acre-foot = 1,234 cubic meters.

1 acre = 0.4047 hectares.

Figure 17. Irrigated acreage.



1 acre-foot = 1,234 cubic meters.

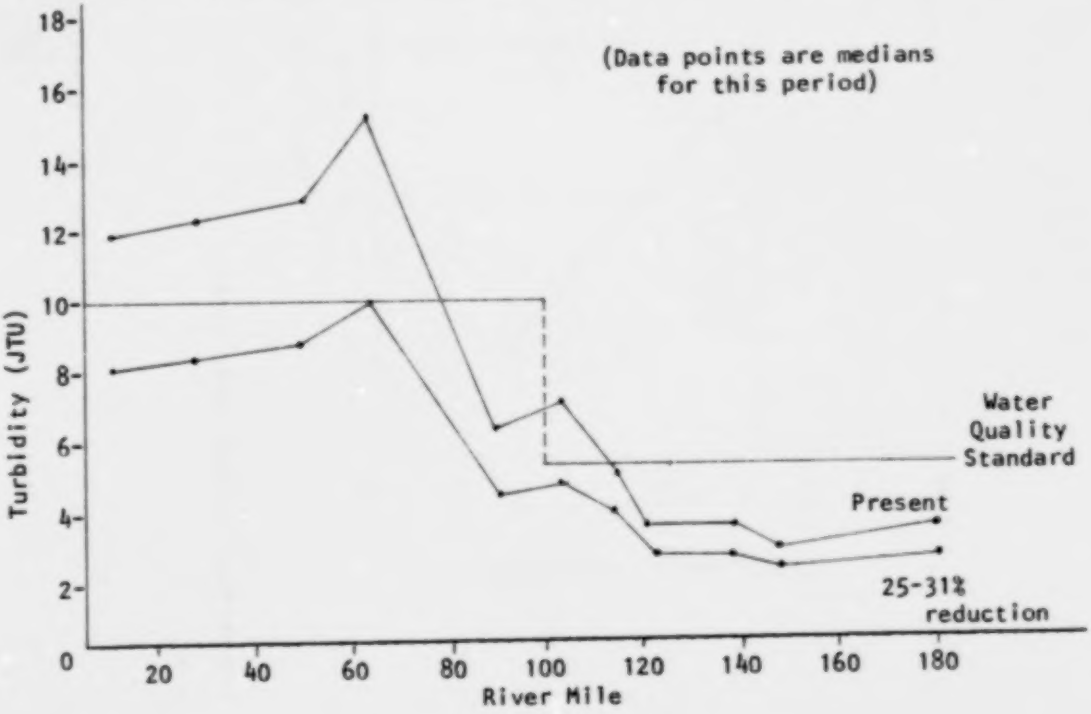
1 acre = 0.4047 hectares.

Figure 18. Total sediment losses.

Figure 19. In fact, such a reduction would reduce turbidity to nearly one-half of the current standards in many reaches.

If, in fact, the 135,000 (54,634) estimate of additional irrigable acreage (hectares) is accurate, the equilibrium price would be around $50 per acre-foot ($24.31 per thousand m^3), the water application rate would be around 4 acre-feet per acre (12 thousand m^3 per hectare), and the total sediment loss would be reduced to about 180,000 tons (16,329,330 kilograms). The preceding analysis, then, represents a very modest calculation of the rental market's water improvement potential.

A point must be made as to the benefits of a water rental market. Current irrigators would sell about 320,000 acre-feet (395 million cu. m.) of water and receive approximately $4.5 million in payment. This would improve the current irrigator's efficiency by allowing the sale of water with a low marginal value in his current use to users with a high marginal value use, resulting in a greater economic return from his water. The economy as a whole would be benefitted as evidenced in Table 11 by the increase in net crop income from $106,908,000 to nearly $120,000,000. These primary benefits



1 mile = 1.609 kilometers

Figure 19. Yakima River turbidity, 1974 irrigation season (May 1 - October 31).

were calculated by multiplying the per acre net income per crop at each water application rate by the total number of acres irrigated in each case.

Additional secondary benefits would result from improved water quality. State water quality standards for turbidity would be met, the general public would benefit from the increased aesthetic and recreational qualities of the Yakima River, and downstream irrigators would realize reduced sediment damage to sprinkler systems. The fisheries may also benefit from cleaner water; however, the market could exacerbate the low flow problem unless the fishery interests were permitted to enter the market and purchase water for in-stream use. Although the water quality improvement benefits have not been expressed in monetary terms, it appears that these benefits would add substantially to the total benefits resulting from establishing a water rental market.

But the key question remains that of a water rental market implementation. It is obvious that the creation of a water rental market would involve significant physical, legal and social changes. The current system of water delivery in the Yakima Basin is generally based on a continuous flow delivery. The majority of the irrigators in the Valley simply open their head gates at the beginning of the irrigation season and the water continues to flow throughout the season. The irrigator then rotates that flow among his fields. With a continuous flow system, the delivery structures are designed for carrying small amounts of water. Particularly at the lower end of an irrigation system, the canals and ditches have very limited capacity. The creation of a water rental market would require structural extension and expansion of delivery systems. This would be necessary in order that any irrigator who desires to purchase additional water could have that water delivered to his land. It would also be required in order to extend irrigation to currently non-irrigated land. Another structural change that would be required would be the careful measurement of quantities of water delivered to each irrigator. This would require additional manpower and the installation of accurate measuring devices. A final physical problem that would result from market establishment would be the reduction in return flow and/or the change in the point of return to the river. Detailed hydrological modeling would be required to predict the effect of this phenomena. Such hydrologic modeling would then play an important part in the total management of the river basin.

The creation of the water rental market would also involve several legal changes. Annual water allotments must be made legally transferrable. This would involve not only changes in Bureau of Reclamation administration, but also clarification of water rights in the basin. Before irrigators can be allowed to freely rent their water, the extent of their water right must be determined and limited. Unless there was a reajudication of all water rights in the Basin, the courts would be flooded with water rights disputes arising from water transfers. Rather than handling these cases on a piecemeal basis, a general adjudication would be preferable and perhaps necessary to add certainly and stability to a market process.

The tremendous complexity of such readjudication has been suggested by both state officials and local individuals involved in water allocation. Estimates of between five and ten years were given as the time required to complete such an adjudication. A 1967 study estimated the cost of a typical adjudication involving approximately thirty claimants at around $2,000. That figure only included administrative costs for title reports, the salaries of the referee, attorney general and survey crew, and other miscelleneous expenses. These costs are exclusive of attorney fees for the water right claimants. An adjudication involving thirty claimants has a potential of 870 controversies. In an adjudication involving 1,000 claimants, the potential controversies arise to 990,000. An adjudication of the entire Yakima Basin could involve thousands of claimants. The administrative costs alone could easily approach $10 million or more.

Finally, it is expected that there may be considerable social resistance to some of the changes that would be involved in a water rental market creation. Two areas of probable resistance are particularly noteworthy. First, water right holders in the Valley fear an adjudication because the amount of water they are presently receiving may be reduced thereby. This fear is further accentuated by the threat of that the Yakima Indian nation may claim a much greater quantity of the water than they are now receiving. Recent court decisions involving Indian water rights have allowed the Indians to divert all the water which they can beneficially use. Secondly, the irrigators may resist the increased level of measurement that would accompany water rental market activity. It has been estimated that the farmer probably receives at least 30 percent more water than the amount for which he is currently charged. Thus, there is some initial risk involved in the creation of a water market. However, it seems that increased certainty, flexibility and profits may compensate for that initial risk.

Internalizing Externalities--

Most professional economists strongly endorse effluent charges or taxes as a method for internalizing externalities (i.e., reducing pollution). Influent charges represent the same basic principle and, while being a newer concept, could expect to also be embraced. The potential benefits of these plans are well documented in the literature. On the other hand, arguments for effluent charges have not had a substantial effect on environmental policy. There are several reasons for this divergence between the views of economists and the actions of government.

Strong resistance to effluent charges obviously exists among those who would be potentially taxed. By internalizing these costs of production, their production costs would increase and, therefore, decrease their progit margin. This group has a strong incentive to lobby against such charges.

There is also the question of property rights. In the case of agriculture, farmers may claim that they have a previous right to affect the quality of the water since their use predates those now in conflict. While the legal basis of this argument is highly questionable, it nevertheless represents a constraint to the implementation of effluent charges. The idea of an effluent tax is also resisted simply because it is a tax. Taxes, in general, have historically been resisted and an effluent tax, in particular, represents a radical departure from current taxing policies.

Finally, there exists a bias among both government and business for legal standards rather than taxes. Government's bias seems to exist largely due to greater familiarity of government personnel with legal measures. Business, on the other hand, argues that once standards have been established it is unnecessary and redundant to impose taxes.

Subsidies enjoy, perhaps, more popular acceptance than taxes. The reasons seem obvious. The polluter is rewarded for cleaning up pollution rather than penalized for polluting. Moreover, the source of thesubsidy is generally spread over a large population so that individual costs are small. A tax on polluters, on the other hand, may have large individual costs. Resistance to subsidies, therefore, is diffuse.

Ultimately, the desirability of either a tax or a subsidy must depend not on how vocal special interest groups can be, but on a weighing of the social benefits and costs. Only when these benefits exceed the costs can such programs be judged to be socially desirable.

Legal Evaluation

As mentioned in the introduction to this section, only solutions that were considered implementable were described in some detail. Thus, the overall research team evaluation took on two steps--the initial concern for what particular solutions have applicability in the Yakima Valley; and a more detailed consideration based on group feedback of what solutions can be integrated with the other disciplinary perspectives in order to produce a feasible and acceptable approach to the problem-solving task and to an eventual implementation strategy.

The three basic legal solutions described in the previous section are considered the essential approaches for both short- and long-run success in controlling the quality of irrigation return flows within the current state water laws and federal reclamation laws. In this regard, a more detailed and comprehensive approach has been suggested for the 17 western states by Radosevich and Skogerboe in their EPA report to be published in late 1977 entitled "Achieving Irrigation Return Flow Quality Control Through Improved Legal Systems."

The solution centering around the provision of criteria for beneficial use and enforcement of these criteria is considered not only realistic but imperative in resolving the dilemma of irrigation return flow quality control. Because of the interdependence that exists between the manner of exercising a water right and the quality of return flows that arises from seepage, percolation and tailwater runoff, any logical solution requires the legal and administrative recognition of this physical relationship. The one element that touches both the action and the consequence is the concept of beneficial use.

Research and demonstration projects have shown that proper water management will reduce degradation in return flows in areas where the degradation is significant. By defining criteria for water delivery, application and removal, the erosion and sediment problem found in the Yakima Valley can be addressed at the source of the problem in a preventative manner rather than treating the solution in an expensive corrective fashion.

From a legal point of view, the willingness and success of administrative agency action to enforce beneficial use will be vastly increased when the person(s) or entities causing or contributing to the problem are placed on the defensive by having to prove their actions within the criteria for beneficial use established by the agency. At the same time, the water user can remain protected from the capricious or ill-founded allocations by the requirement that the agency demonstrate that the criteria have been necessitated.

Removing the transfer restrictions can be a somewhat more difficult task. Again, from the Washington water law point of view, there are no unreasonable restrictions. At the federal law level, reallocation of water within irrigation districts to other certified lands is a practice very common. In fact, many irrigation districts have a "transfer book." It is considered legal, feasible and appropriate that the irrigation districts in the Yakima Valley would also enter into a cooperative sharing of total water rights held by the various districts collectively, with the concurrence of the Bureau of Reclamation and DOE.

The last legal solution concerns the stimulation of the use of low or no interest funding for water quality improvements by irrigation districts and individauls in areas where the quality of return flow is a probelm. This would require a policy change and program reorientation. But, this incentive is well within existing precedent for water quality improvement funding to non-point source discharges in the municipal and industrial categories. Part of the difficulty is to determine how significant the problem from irrigated agriculture is, and if it really is considered significant this would justify policy and program modification.

Social Evaluation

The critical concern regarding the solutions is to have the individual water user involved in a program to clean up irrigation return flows. While the main report of this research centers on the process of implementation of such a program, the present section concentrates on some specific exemplary solutions that may allow the desired involvement. In any case, at both the individual and the organizational levels, the solutions are designed to stimulate involvement through a process of awareness and legitimization.

At the individual level, the awareness to the problem begins by showing the people the problem and the contribution made by irrigation to the problem. Yet, it is obvious that awareness alone will not necessarily induce action. One must also have the information available to know how to solve the problem. The purpose of the solution calling for more research is to provide that information to provide a greater range of alternatives for the individual water user. Finally, the ability to get people involved in an implementation process concerned with the introduction of new water management practices will depend on how such a process is managed.

The development of a common definition of the problem is a necessary part of providing the impetus for a concentrated type of action. Obtaining this definition may be difficult and it may end up being nothing more than a set of parameters that are influenced by individual operations. Yet, if the procedure for determining an intolerable degree of degradation is accepted, a motivating basis for further action will be established.

Finally, creating a greater degree of participation in irrigation district matters will provide the framework for greater involvement. It may not make the implementation of any single alternative easier, but it can create a situation in which the seeds of change can be more easily planted and further steps undertaken.

As previously stated, unless there is an organizational network that is supportive of change, the emphasis on the individual user alone will not prove to be the most effective mechanism to create change. The same strategy of awareness, information, legitimacy, and involvement applies to the organizational level as well as to the individual. Thus, organizational solutions emphasize the obtaining of knowledge and the ability to disseminate information as critical features for setting the stage for legitimacy and involvement. Legitimacy can be achieved by establishing a clear-cut authoritative structure and by utilizing this authority in an appropriate manner. The thrust of all involvement efforts during an implementation process rests also on the establishment of a regional authority. This organizational mechanism can create a situation that increases awareness, produces information, establishes legitimacy, and promotes involvement. At the end, it can become the institutional framework from which strategies emphasizing individual involvement can emerge.

In conclusion, in evaluating the social situation and the solutions evolving out of this situation, there is one critical overriding concern: both the individual water user and the organizational network surrounding that user regarding irrigation must be the focus of concern. Programs involving water management procedures must be flexible enough to include the specific individual situation while, at the same time, the overall objectives of a clean water program are carried out. This implies an organizational structure that facilitates individual involvement so that change (shared and legitimized) can be carried out. This type of program will demand extensive resources both in manpower and money in order to be administered appropriately.

The broad concluding remarks of a social evaluation of potential solutions brings full circle the general effort of assessing through interdisciplinary dialogue the research team's estimation of the range of approaches suggested with regard to irrigation return flow quality measures. At this point, field "testing" of the team's assessment becomes imperative.

FIELD ASSESSMENT OF POTENTIAL SOLUTIONS

The research team's preliminary evaluation and screening of alternative measures for improving irrigation return flow quality resulted in a summary table of possible solutions along with a preliminary indication of their benefits and costs. This information is summarized in Table 12. Possible solutions are categorized with respect to the stage of water use at which they

TABLE 12. SUMMARY EVALUATION OF MEASURES TO IMPROVE IRRIGATION RETURN FLOW QUALITY.

MEASURES	BENEFITS				COSTS		DESIRABILITY	CONSTRAINTS
	Water Quality Improvement			Other	Monetary	Other		
	Sediment	Phosphate	Nitrate					
1. **RETURN FLOW** A. Discharge Permit System	Variable with quota levels permitted.			Possible incentive to more efficient farming. Reduction of downstream costs of water use. Increased recreational value. Some improvement to fisheries. Greater control over small part-time farmers.	Very high monitoring and enforcement costs.	Loss of farmer's control of operations. Increased strain within irrigation districts and between users and officials. Increased litigation.	Farmers and state officials unenthusiastic. Federal support for program.	Resistance to arbitrary outside restrictions. Enforcement difficult due to local resistance and lack of evidence.
B. Effluent Tax	Variable with tax level.			Revenues for additional adjustments. Incentives to more efficient farming. Reduction of downstream costs of water use. Increased recrea. value. Some improvement to fish. Burden of pollution control on those who benefit from water use.	Very high monitoring and enforcement costs.	Tax may act as a disincentive to farming. Creation of strain between users and taxing officials.	No clear support for this action.	Resistance to taxation. Difficult to equitably determine who should be taxes and how much.
C. District or Area Treatment	100%	90%	90%	Large reduction of downstream water use costs. Increased recrea. value. Some improvement to fish. Possibility of greater unity and coordination among districts.	$1.3-$10.2 million-capital costs + $75,000-$1,740,000-operation and maintenance cost per year.	Increased organizational growth.	General reluctance to paying the high costs of this measure.	Farmer resistance to financing; or Public resistance to financing.
D. Subsidies on On-Farm Treatment	90%	60%	40%	Reduce farmer's financial burden of adjustment. Large reduction of downstream water use costs. Some improvement to fish. Incentive to more efficient farming. Greater integration of farmer into water quality arena.	$240,000-capital costs + $75,000 O&M per year.	Complicates farmer's operations. Outside interference in farm operations.	Farmers may support this measure.	Difficulty in financing-public resistance. Not effective for farmers who cannot or will not obtain subsidies.

(continued)

TABLE 12 (continued)

MEASURES	BENEFITS				COSTS		DESIRABILITY	CONSTRAINTS
	Water Quality Improvement							
	Sediment	Phosphate	Nitrate	Other	Monetary	Other		
II. ON-FARM PRACTICES								
A. Improved Tailwater Management	90%	90%	10%	Prevention of soil loss Reduction of downstream water use costs. Some improvement to fish.	$20/acre-capital costs; + $6 acre-O&M per year.	Complicates farmer's operations.		
B. Tailwater Ponds with Recirculation	100%	100%	40%	Prevention of soil loss. Lower water & fertilizer needs. Reduction of downstream water use costs. Large improvements to recrea. and fish (less diversion from river).	$250/acre-capital costs; + $12/acre-O&M per year.	Complicates farmer's operations. Possible damage to downstream water rights due to reduced return flow.	This is practiced in Wapato Project currently.	Low cost, abundant water supplies inhibit reuse practices. Courts may rule against such measures due to injury to downstream users.
B. Improved Application Methods								
1) Contour Furrows	70%	70%	10%	Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries.	Labor costs increase.	Complicates farmer's operations.		Resistance to a more time consuming practice.
2) Sprinkler Irrigation	100%	100%	70%	Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries. Frost protection. Lower water needs Lower labor needs.	$225-$1,500/acre-capital costs; + $56-$121/acre O&M.	Complicates farmer's operations.	More farmers are installing sprinklers for many of the benefits in "other" column each year.	High capital costs.
3) Trickle Irrigation	100%	100%	90%	Prevention of soil loss Reduction in downstream costs. Improvement in recreation and fisheries. Increased productivity. Lower water needs. Lower labor needs.	$1,000-$1,300/acre.	Complicates farmer's operations.		Past bad experience with trickle systems. High capital costs.
C. Improved Land and Water Management 1) Precise Water Measurement	Varies with resulting decrease in water application.			Better data for resource planning. Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries.	Measuring devices and labor costs.	Complicates farmer's operations.	Some farmers are currently using these practices to a degree. This suggests at least acceptability and desirability.	Farmers will resist any decrease in their water deliveries.
2) Irrigation Scheduling	30%	30%	50%	Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries. Increased production. Lower water and fertilizer needs.	Computer costs, technical assistance costs, increased on-farm labor costs.	Less flexibility for farmer.	Some farmers are currently using these practices to a degree. This suggests at least acceptability and desirability.	Resistance to change to more complex, time-consuming practices.

(continued)

TABLE 12 (continued)

MEASURES	BENEFITS				COSTS		DESIRABILITY	CONSTRAINTS
	Water Quality Improvement			Other	Monetary	Other		
	Sed	Phos	Nit					
3) Improved Fertilizer Practices	0%	50%	70%	Lower fertilizer needs.	Educational program costs. Increased application costs.	Farmer uncertainty with new practices.	Some farmers are now using these practices to a degree. This suggests at least acceptability & desirability.	Resistance to change to more complex, time-consuming practices.
4) Improved Cropping Patterns	Variable			Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries.	Educational program costs.	Farmer uncertainty with new practices.	Some farmers are now using these practices to a degree. This suggests at least acceptability & desirability.	Resistance to change to more complex, time-consuming practices.
5) Improved Cultivation Practices	Variable			Prevention of soil loss. Reduction in downstream costs. Improvement to recrea. and fisheries.	Equipment and labor costs increase. Educational program costs.	Farmer uncertainty with new practices.	Some farmers are now using these practices to a degree. This suggests at least acceptability & desirability.	Resistance to change to more complex, time-consuming practices.
D. Specification of Beneficial Use 1) Quantity by Crop Type, etc.	Variable with levels specified.			Reduce waste. Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries.	Increased manpower in state agencies for specification and monitoring.			
2) To Incorporate Water Quality.	Could attain any desired level of water quality.			Greater water quality control. Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries.	Increased manpower in state agencies for specification and monitoring.			
E. Subsidize Irrigators 1) Technical, Educational Aid.	Will correspond with improvement to be subsidized.			Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries	Higher manpower costs.		Agencies which could handle the subsidies already exist & are generally successful in Yakima area.	Limited funding.
2) Cost-sharing Capital-Improvements	Will correspond with improvement to be subsidized.			Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries	Higher manpower costs. Cost of subsidies.		Agencies which could handle the subsidies already exist & are generally successful in Yakima area.	Limited funding.
3) Incentive Payments	Will correspond with improvement to be subsidized.			Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries.	Higher manpower costs. Cost of subsidies.		Agencies which could handle the subsidies already exist & are generally successful in Yakima area.	

(continued)

TABLE 12 (continued)

MEASURES	BENEFITS				COSTS		DESIRABILITY	CONSTRAINTS
	Water Quality Improvement			Other	Monetary	Other		
	Sed	Phos	Nit					
III. DELIVERY A. Readjudication 1) To eliminate Uncertainty	Will correspond with decrease in water application rate.			Increased certainty of water rights.	Adjudication would take hundreds of man years and cost millions of dollars to complete.	Inducement of conflict.	The feeling in state agencies & among water users is against adjudication proceedings.	Fear of reduction in water rights, especially with Indian claims.
2) To Incorporate Beneficial Use.	Variable with levels specified. Could attain any level of water quality.			Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries.				
3) To allow Districts to Use Return Flow	Will correspond with decrease in water application rate.			Incentive for more efficient water use.				
B. System Rehabilitation	Will provide more water which could be left in stream.			Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries. Better control, less waste.	Very expensive to install new delivery systems.		Broad recognition of need.	Funding source.
C. Tax on Water (at $20/a.f.)	Variable with tax level. 88%	88%	35%	Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries. The polluter pays damages.	Reduces agricultural income. $28,000,000.	Disincentive to farming.	Taxation would find little support.	Resistance to taxation.
D. Water Rental Market	75%	75%	0%	Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries. Increased ag. income-$70,000,000. Increased flexibility. Most efficient water use.	Cost of adjudication if needed.		No clear support.	Uncertain of meaning and effects. Need for readjudication.
E. Demand Delivery System	Uncertain			Reduce waste. Prevention of soil loss. Reduction of downstream costs. Improvement to recrea. and fisheries.	Labor costs increase.	Less flexibility.	Unclear.	Farmers may resist the decreased flexibility.
IV. RIVER FLOW A. Stabilize 1) Additional Storage	Uncertain			Reservoir recreation. High benefit to fisheries. Encourages multiple use of river.	High cost of dam construction.	Possible recreation & wilderness loss.	Strong local support.	Farmers may resist additional indebtedness.
2) Ground	Uncertain			High benefit to fisheries. Encourage multiple use of river. Reservoir recreation.		Possible loss of wildlife habitat dut to lowering water table.	Weak local support.	

would be applicable. The four categories are teturn flow, on-farm practices, on-farm delivery, and river flow.

Table 12 has provided the basic structure and scheme for further evaluation of the possible solutions. Thus, it became the starting point for discussions with state and federal agencies, water managers and water users. The remarks that follow deal with the responses of these groups in terms of the four categories of adjustments identified. It should be noted that from a hydrologic standpoint, the discussion is backwards, i.e., working upstream. This is intentional, however, since experience in other areas indicated that by initially discussing the most familiar topic, namely the NPDES program at the field, not only interest was generated but a more free-flowing discussion of problems and proposed solutions became possible.

Return Flow Adjustments

Return flow measures include: a) the discharge permit system; b) an effluent tax; c) distinct or area treatment; and d) subsidies to on-farm treatment. The discharge permit system is the same as the current NPDES program. An effluent tax program would attempt to regulate return flow pollution by assessing an increasingly greater tax on higher levels of pollution. District or area treatment would treat return flow ater before it reaches the river. Finally, subsidies to on-farm treatment would encourage farmers to treat their own return flow before it reaches the river either through direct cash payments or with construction assistance.

In general, there was agreement among those interviewed that the water quality improvement benefits of the discharge permit system would vary with the quota levels permitted. Furthermore, it was generally agreed that a permit system could be a possible incentive to more efficient farming; it would reduce downstream costs of water use and increase the recreational value of the river; and it would provide greater control over small, part-time farmers. Considerable disagreement exists, however, with the role of the small farmer, whether he is part-time or not. Typically, administrators at all levels have a tendency to view the small farmer as inefficient and, consequently, as a significant source of return flow pollution, The small farmers, on the other hand, argue that because of their size they expend greater managerial effort per unit of land than do the very large farmers and, therefore, represent an insignificant share of the problem. The small farmer also sees many of the measures proposed as having a disproportionate cost for them as compared to their contribution to the problem. Finally, while most people interviewed did not respond to the permit system's effect on fisheries, those that did so agreed that the effect would be positive.

Generally, the discharge permit system is not very popular with any of the groups interviewed. It is most popular with state and Federal agency people who see it as a "club" to force poor irrigators to improve their operations. Water managers and especially water users tend not to favor the permit system and view it as a penalty on good farmers. Moreover, they argue, and perhaps not surprisingly so, that the emphasis should be on voluntary action by the farmers.

The monetary costs of the discharge permit system are recognized to be high by all groups interviewed, because of the necessity of monitoring and enforcing the permits. Other costs are generally nonpecuniary and accrue at the local level. While state and federal agencies tend to discount such costs, water managers and users recognize the costs in terms of the loss of a farmer's control over his operations, increased strain within irrigation districts and pecuniary as well as social costs of continuous litigation. Most support for the permit system is found at the federal level. State agencies, particularly the Department of Ecology, are less enthusiastic, though there is some attraction to such a scheme. Water managers and users are almost universally opposed to such a system. Thus, the major constraint to implementation of the permit system is strong resistance at the local level. Needless to say, the difficulty of administering the permit system adds to this resistance and to a wider acceptability of such an approach to controlling return flow.

There was less reaction to the effluent tax plan than to the permit system. This is interesting since administratively both approaches are very similar. The difference, of course, is that the permit system has become more familiar and a focal point of the entire debate concerning water pollution from agriculture. Most persons interviewed agreed that the water quality benefits realized from an effluent tax would depend upon the tax level. Other recognizable benefits of this alternative are that it would generate revenues which could be used for other water quality improvement measures. It would also provide an incentive for more efficient farming, downstream water use costs would be reduced, the recreational value of the river would be increased, there might be some improvement of fisheries, and, finally, the burden of pollution reduction would be placed on those polluting the water. Like the permit system, however, the effluent tax would have high monitoring and enforcement costs. Also, it could provide a disincentive to some farming and create a strain between the farmers and the taxing body (i.e., the state or federal government). In the interviews conducted, there was no clear support nor opposition to this plan. Often responses indicated a lack of understanding. In this regard, constraints to the implementation of such a plan would include a resistance to taxation in general as well as the concern of many with the equitable administration of such a tax.

District or area treatment of return flow has potentially large water quality benefits. Other benefits of such a measure would include reduced downstream water use costs, increased recreational value of the river, improved fisheries and the possibility of greater unity and coordination among the irrigation districts. Costs of such a measure, however, are also large. depending upon the size of such facilities, capital costs could range from \$1.3 to \$10.2 million and operating and maintenance costs could range from \$75,000 to \$1,740,000. Furthermore, there would also be the associated costs of organizational growth.

Typically, there is resistance to the district or area treatment alternative. In part, this is a function of the large pecuniary costs of such a system. There is also the feeling that the problem of coordination and control of such a system is unsolvable within current financial and institutional constraints. In large part, the seemingly unequal distribution of benefits and costs of such a system represents the major constraint to its adoption.

Subsidies to on-farm treatment of return flow could reduce sediment significantly and phosphates and nitrates to a lesser degree. However, the non-pecuniary benefits listed for the previous adjustments would also be present. Capital costs would be approximately $240,000 with operation and maintenance costs of $75,000 per year. Additionally, such a system could complicate a farmer's operations and impose outside interferences on his activities with all associated social costs for running an extensive program. The desirability of this alternative is largely a function of the source and size of the subsidies. Farmers resist financing such a plan themselves and desire most of the support to come from other sources. Similarly, government agencies look to some higher source for funding. Again, a major difficulty of this plan is associating benefits with costs.

On-Farm Adjustments

The on-farm measures include: a) improved tailwater management, either through tailwater ponds or tailwater ponds with recirculation; b) improved application methods through contour furrows, sprinkler irrigation, or trickle irrigation; c) improved land and water management through precise water measurement, irrigation scheduling, improved fertilizer practices, improved cropping patterns, or improved cultivation practices; d) specification of beneficial use through restrictions of quantity by crop type or an incorporation of water quality considerations in water rights; and, 3) subsidization of irrigators to provide technical and educational aid, cost-sharing of capital improvements, or incentive payments for water quality improvements.

With regard to the field assessment of each of the above, improved tailwater management could significantly reduce sediment and phosphates, but would only reduce nitrates slightly. Other benefits would include the prevention of soil loss, reduction of downstream water use and costs and increased recreational and fisheries value. In addition, recirculation could reduce water and fertilizer needs. Tailwater ponds have a capital cost of approximately $50 per hectare ($20 per acre) and operation and maintenance costs of $15 per hectare ($6 per acre) per year. Tailwater ponds with recirculation have capital costs of $620 per hectare ($250 per acre) and operation and maintenance costs of $25 per hectare ($12 per acre) per year. Both tailwater management schemes have the potential of complicating the farmer's operations, while recirculation might also damage downstream water rights. That improved tailwater management through the use of tailwater ponds is desirable can be deduced from the widespread current application of such measures in the Yakima Valley. Recirculation is even practiced in one district--the Wapato. Constraints to adoption of this measure include some farmers' short-run lack of concern for soil loss, the relatively low cost and abundant supply of water and legal uncertainties regarding junior rights.

It is generally agreed that various measures for improving water application methods could have significant beneficial effects on water quality, especially sedimentation. Moreover, in addition to the benefits directly associated with improved water quality, such measures could also benefit the land. Of the three measures identified for improving application of water, contour furrows have the lowest anticipated water quality benefits. Both sprinkler and trickle irrigation methods have potentially large water quality benefits, as well as the general potential for increasing productivity. Sprinkler irrigation has the additional advantage of being able to be adapted to frost protection.

Contour furrows, however, increase labor costs. Sprinkler irrigation entails capital costs of from $550 to $3,700 per hectare ($225 to $1,500 per acre), plus operation and maintenance costs of $140 to $300 per hectare ($56 to $121 per acre). And, trickle irrigation costs roughly $2,500 to $3,200 per hectare ($1,000 to $1,300 per acre). But, above everything else, all such measures tend to increase the complexity of the farmer's operation.

Of the three methods of improving water application, sprinkler irrigation is the most favored in the Yakima Valley. This derives from its dual purpose, i.e., irrigation and frost protection. On the one hand, rising labor costs have made more capital intensive practices more attractive; and, on the other hand, increased air quality standards have made traditional frost protection devices which burn various substances less desirable. The growth of sprinkler irrigation in the Valley is impressive, but it has not been directly induced by water quality considerations. Trickle irrigation seems to have a bad reputation in the Valley due to uneven experience with its earlier introduction. The first trickle systems were improperly designed and installed and functioned poorly. Finally, contour furrows are resisted because of their additional time requirements in construction and maintenance.

Anticipated water quality benefits from improved land and water management measures can not be clearly delineated due to the variability of application of these measures. Precise water management is seen as a means of facilitating water management through the availability of better data. Irrigation scheduling and improved fertilizer practices could reduce phosphates and nitrates in return flow while simultaneously lowering fertilizer needs. Improved cropping patterns and cultivation practices may also contribute to water quality. The costs associated with these alternatives do not appear particularly high. Nevertheless, some farmers, although aware of these measures, have not voluntarily adopted them, while others have. Education and/or financial constraints do not appear significant. Resistance to change, partly the result of adherence to traditional practices, however, is perhaps the most significant constraint along with uncertainties of outcome of changes for a given farmer.

The specification of beneficial use alternatives could improve return flow quality through a restricting of the amount of water applied by crop or by incorporating quality considerations into use rights. Either alternative seems capable of producing significant water quality benefits along with all other ancillary benefits identified above. Costs are largely in terms of additional manpower requirements for specification and administration of law. State and federal agencies are generally favorable to this idea; farmers represent the major potential constraint because of uncertainty on their part with respect to consequences for them or the far-reaching effects of such a measure.

Finally, irrigators may be subsidized either through technical and educational aid, cost-sharing of capital improvements, or incentive payments. Water quality benefits would correspond with the improvement to be subsidized. Costs would involve the subsidy itself and management costs. In large part, the agencies which could administer such subsidies already exist and do successfully administer subsidies in the Yakima Valley. The major constraint to this adjustment is the availability of funding as well as the question of who would pay and who would obtain the benefits.

Delivery Adjustments

Possible solutions related to the delivery system include: a) reajudication either to eliminate uncertainty regarding the quantity of water allotted, to incorporate the concept of beneficial use, or to allow districts ot utilize return flow; b) system rehabilitation; c) a tax on water in order to reduce its wasteful use; d) creation of a water rental market; and e) establishment of a demand delivery system. Generally, it was agreed by those interviewed that the major cause of return flow pollution in the Yakima Valley is that farmers receive and use excess quantities of water. In other words, the delivery or allocation system is faulty. The adjustments and reactions discussed in this section revolve around potential corrections of this fault.

Readjudication of water rights would have varying benefits depending upon the intent of the readjudication. In general, the benefits would vary directly with the resulting decrease in water application. Additional benefits would include increased certainty of water rights, soil loss prevention, reduced downstream costs, improved recreation and fisheries and an incentive for more efficient water use. The costs of readjudication are difficult to assess, but experiences from other areas indicate that they may be in terms of hundreds of man years, millions of dollars, and of unmeasurable social conflict. Even more, among those interviewed, considerable disagreement existed regarding these costs and their allocation.

There was little support by either the agencies, water managers, or water users for readjudication. The major fear centered around the uncertainty of the eventual outcome of such an action. Of particular concern was the question of the water rights of the Yakima Indians in the Wapato District. Court decisions involving water rights of Indians in other states are viewed by non-Indians in the Yakima Valley as favoring the Indians to the detriment of the rest of the population. No wonder, then, that few non-Indian water right holders favor a reexamination of these rights.

System rehabilitation is anticipated to benefit water quality by allowing more water to remain in the stream and by improving the monitoring and control of the water diverted. In addition, there would be downstream benefits to water users, fisheries and recreation. The dollar cost of such an adjustment, however, would be particularly high.

The water quality benefits of a tax on water, although potentially large, vary with the level of taxation. In addition, benefits would include the prevention of soil loss, reduced downstream costs of water use, improved recreation and fisheries, and perhaps, most importantly, the potential polluter would be paying the cost. On the cost side, there would be a redistribution of income with agricultural incomes potentially declining. Many agency, water manager and water user personnel, however, viewed such a measure as a viable future alternative. In part, this acceptance is a function of their realization that the current system of taxing land with water heavier than land without water is a form of a tax on water. Overall, constraints to such an adjustment include the general resistance to taxation, the Bureau of Reclamation's lack of legal ability to increase water prices, questions regarding water quality effects, and concern over the distribution of tax revenues generated.

A water rental market has large potential water quality benefits as well as preventing soil loss, reducing downstream water use costs and improving recreation and fisheries. Moreover, farm incomes could be increased by approximately $70 million while increasing the farmer's flexibility and physical efficiency of water use. The major cost of this adjustment seems to be the likely need for a readjudication of water rights. Among those interviewed, there was no clear support for this adjustment. This reaction seems to be largely due to a lack of familiarity or exposure to this alternative. Furthermore, there is always in the background pervasive concern and apprehension with the possible need for the readjudication of water rights.

It is not clear what the water quality benefits of a demand delivery system would be. Such a system would appear to reduce waste and to contribute to such things as reducing soil loss, reducing downstream water use costs, and increasing recreational and fisheries values. Such a system would entail higher labor costs, particularly for management. It might also reduce individual farmer flexibility. Desirability of such an approach was seldom made clear, perhaps because of a lack of specification of its operation. Farmers did perceive the potential of a system to restrict their operations but did not find such an approach desirable.

River Flow Adjustments

Measures to stabilize and perhaps augment river flow include the construction of additional storage facilities upstream and ground water pumping. The water quality benefits of these measures are not certain, but the anticipated benefits would be in terms of diluting existing pollutants. Additional benefits would include large benefits to the lower river fisheries, possible multiple use of the river, and advantages from recreation on reservoirs constructed. Both options for adjusting river flow would have high capital costs, with the construction of additional storage being the highest. Other costs might include loss of wilderness and recreation and destruction of wildlife habitats. Within the Valley, both water managers and users favor additional storage. The Bumping Lake Project to construct more storage has had strong local support. This support, however, is largely a function of the desire for more water and is not necessarily due to any concern with water quality. The major constraint to additional storage is the construction cost and the farmer's resistance to more indebtedness.

Ground water pumping is typically resisted by local farmers due to its initial capital costs of $5,000 to $10,000 per well and operation costs of

$7 to $10 per acre. Furthermore, rising energy costs are anticipated to further increase such operating costs.

The field assessment of potential solutions provided a realistic backdrop against which further sharpening of the range of alternatives, their advantages and disadvantages, and appropriate trade-offs could be pursued. In terms of developing a basis for implementation, a final evaluation must be made as to the evolution of cogent "packages" of appropriate, acceptable and implementable solutions.

SUMMARY OF TESTING RESULTS

As outlined previously, a first evaluation was conducted by the project team. Composed as it was of engineers, economists, sociologists, and an attorney, the team was able to judge alternative solutions in terms of criteria of general technical, economic, legal, and social feasibility. Obviously inappropriate and ill-advised solutions were immediately weeded out, though their number was not great to start with. Alternatives with potential for significant impacts on the water quality problem and those without prohibitive costs were left for evaluation by others. The team wanted to present the widest possible range of alternatives to succeeding evaluators and to the field for "testing" as to their appropriateness, feasibility and acceptability.

A second evaluation was accomplished by federal and state agency personnel, chiefly those presently or prospectively involved in administration of quality improvement programs. The alternative solutions were thus screened by those with technical and legal expertise, a group with a special concern for administration of laws and programs. This group tended to sort out those solutions which did not fit within the framework of existing laws, rules and regulations, and which would, therefore, be difficult to implement. The list of alternatives was reduced, but not so as to exclude some solutions which would be possible with changes in laws, rules and regulations.

A third evaluation was completed by managers of water supply agencies (e.g., irrigation companies and districts) and their boards of directors. These individuals having responsibility for distribution of water among farms of members and patrons and for maintenance of system facilities. Because they are potentially responsible for administration of revised rules governing diversions and use of water, they tended to resist measures of control. But they were aware of water quality problems; they were generally convinced of possibilities for improved use of water; and they tended to favor quality control measures located and administered at their level rather than at higher or lower levels.

Finally, a fourth evaluation was done by users of water, i.e., farmers who use water in irrigation of crops. They were interviewed one at a time. During the interviews, there were extensive discussions as to return flow quality problems and as to potentially useful solutions. These individuals, though alarmed by present efforts to control their use of water, showed both ability and willingness to comprehend problems of water quality and to deal with them. They were very practical in their judgments of implementability of the various alternative solutions, and they generally tended to favor those measures aimed at improved use of water in agriculture. Obviously, these were the types of measures and solutions over which they had some control.

Looking over the previous material, the alternative solutions proposed for evaluation ranged from those which were wholly technical (e.g., rehabilitation of distribution systems) to those which were institutional (e.g., creation of water markets). Some were combinations of technical and institutional measures which would cause improvements in quality of return flows (e.g., cost-sharing arrangements for improved irrigation facilities). They can be generally classed as:

a. those which were concerned with the effluent, i.e., the return flow;

b. those concerned with the influent, i.e., the water diverted to agriculture;

c. those associated with the management of land and water on farms; and

d. those directed to sources of water, generally those which would increase supply.

Responses to all such solutions depended somewhat on who was doing the evaluating. Administrators were more inclined to favor technical solutions since they were the ones most familiar to the agency personnel. They were inclined to prefer measures that they could control and administer, as their experience was largely with water development and water treatment. Users tended to prefer those solutions which emphasized management of water in agriculture. They were aware of some inefficiencies in water use and they knew of possibilities for improved management. Managers of distribution systems were aware of inadequacies in their systems and liked generally proposals for improvement. They tended to favor the influent control measures, i.e., solutions affecting diversion and allocation of water among users. Farmers understood these solutions, too, but were understandably concerned about possible reductions in their annual allocations.

Probably the greatest support was found for those solutions that dealt with improved management of water in agriculture. There was appreciation in most of the project areas for the efficacy of those measures that affected on-farm use. But there was also appreciation for solutions proposing new controls on diversions and use, for in two of the project areas water allocations are usually large, i.e., there is an abundant supply. The managers of distribution systems and farmer-users of water know that greater efficiencies in water use can be achieved. Their concern is for loss of rights which have been long held and traditionally carefully guarded. There was some interest in water markets, as means for reallocating supplies, but unfamiliarity with such a measure and lack of specificity prevented enthusiastic support.

The "testing" process itself as part of the assessment of potential solutions can be judged both a success and a failure. It was a success in terms of the objective of this study, namely, building the basis for implementing measures for improving irrigation return flow quality. It failed, however, in the sense of clearly defining a specific program for implementation. This should not be surprising. After all, one can see in all previous pages the extensive range of technical solutions and the relative paucity of institutional measures. The jump from appropriate solutions to implementation strategies requires a much wider strategy of social mobilization and of strategic interventions through interlocking steps of problem identification, generation of alternatives, assessment, evaluation, and public acceptance.

Thus, the assessment process and especially reality "testing" is iterative in that it involves the mutual education of those performing the testing as well as those being tested. That is, the testing process is not one of determining absolutes, but of providing a dialogue leading to possible combinations of packages of alternative solutions. Possible solutions were modified, added or deleted during the testing process as the research team became more aware of intricacies and specificities of the problem. On the other hand, responses from federal and state agency personnel, water managers and water users tended to alter over time as they too became more aware and better educated in the problem.

Perhaps the flexibility of the assessment process was its greatest attribute and the vital element in the building of an implementation basis. While the laboratory scientist might hesitate to identify the process as a test, it produced greater insights and the potential for long-run solutions which no rigid experiment could have provided. The flexibility of the assessment process contributed also to the productivity of the effort. In the most succinct form possible, the major conclusion is that the heart of the problem rests with the institutional framework through which water is managed. Even more, this framework is not immutable but can be changed from both within and from exogenous forces.

While the assessment process did not identify a specific solution for problems of irrigation return flow in the Valley, it did generate possible solution packages. In discussing individual solutions with various agencies, water managers and water users, inevitably the discussion would lead to the identification of one or more possible combinations as being the optimum mix.

Needless to say, the tendency was to identify the physical adjustments as the first step. In part, this probably follows from the greater familiarity with such measures, as well as with the visibility and immediacy of technological solutions. But almost immediately these physical solutions were amended with or qualified by social, legal and economic considerations.

For example, physical measures to improve on-farm management tended to be popular, but with these adjustments were nearly always combined economic schemes to share the cost of constructing these improvements. Also, most individuals interviewed were reluctant to foresake the legal option of penalizing those water users not responding to inducements to improve on-farm water management. Finally, the social acceptance of any plan was of prime concern. Since practically all those interviewed were in the administration and implementation side of the problem rather than the funding side, social acceptability was normally viewed as being enhanced by the "carrot" as opposed to the "stick" approach.

In the final analysis, no universal solution package evolved from the assessment process. The assessment process, in fact, was not designed to develop such a package. It could, however, be easily used for developing solution packages, since it now is obvious that the types of persons interviewed exhibited also the tendency to think in holistic rather than atomistic terms.

Finally, it should not be forgotten that the thrust of this research was not to provide the "solution" to problems of irrigation return flow in any of the case studies. The process itself (of generating appropriate solutions and of testing for their eventual implementability) was the focus of attention as the central axis for articulating in the main report necessary steps that would link the problem, potential solutions and attainable strategies into definable means for implementing both the spirit and the letter of PL 92-500 and of the broader social wish for a safe, productive and fulfilling environment.

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APPENDIX A

TABLE A1: SOCIAL CHARACTERISTICS--YAKIMA VALLEY: GENERAL POPULATION

County	Median Years of School		Unemployment Rate (%)		Occupation: Farmers & Farm Managers (%)	Median Income	Per Capita Income of Persons
	M	F	M	F			
Kittitas	12.5	12.4	10.1	10.0	5.0	$8524	$2683
Yakima	11.6	12.1	7.6	11.8	5.8	$8062	$2553
Benton	12.5	12.5	6.1	8.0	2.1	$10,656	$3204

SOURCE: U.S. Census of Population (1970).

TABLE A2: SOCIAL CHARACTERISTICS--YAKIMA VALLEY: RURAL NONFARM POPULATION

County	Median Years of School	Industry of the Employed: Agricultural, Forestry & Fisheries (%)	Occupation: Farmers & Farm Managers (%)		Median Income	Per Capita Income
			M	F		
Kittitas	12.1	10.9	2.7	0.5	$7992	$2512
Yakima	11.7	19.2	4.3	0.4	$8210	$2404
Benton	12.3	18.8	1.2	0.9	$10092	$2794
					$8764	$2570

SOURCE: U.S. Centus of Population (1970).

TABLE A3: SOCIAL CHARACTERISTICS--YAKIMA VALLEY: RURAL FARM POPULATION

County	Median Years of School	Industry of the Employed: Agricultural, Forestry & Fisheries (%)	Occupation: Farmers & Farm Managers (%)		Median Income	Per Capita Income
			M	F		
Kittitas	12.4	46.9	43.2	9.1	$8873	$3023
Yakima	12.1	48.0	38.9	6.9	$8182	$2584
Benton	12.2	43.7	33.9	1.9	$9216	$2922
					$8757	$2893

SOURCE: U.S. Census of Population (1970).

TABLE A4: POPULATION CHARACTERISTICS--YAKIMA VALLEY: 1960 and 1970

County	Total	1970							1960		
		URBAN				RURAL			Total Total	Urban Urban	Rural Rural
		Total	% Urban	Urbanized Areas	Other Urban	Total	Places 1000-2500	Other Rural			
Kittitas	25,039	13,568	54.2	--	13,568	11,471	2,756	8,715	20,467	8,625	11,842
Yakima	144,971	74,172	51.2	--	74,172	70,799	7,889	62,910	145,112	74,250	70,862
Benton	67,540	44,456	65.8	--	44,456	23,084	2,177	20,907	62,070	40,555	21,515
TOTAL	127,550	132,196				105,354			227,649		

SOURCE: U.S. Census of Population (1970).

TABLE A5: URBAN AREAS IN THE YAKIMA VALLEY

Urban Areas	Population 1970	Population 1960	% Change
Yakima	45,588	43,284	5.3
Richland	26,290	23,548	11.6
Kennewick	15,212	14,244	6.8
Pasco	13,920	14,522	-4.1
Ellensburg	13,568	8,625	57.3
Sunnyside	6,751	6,208	8.7
Toppenish	5,744	5,667	1.4
Grandview	3,605	3,366	7.1
Selah	3,070	2,824	8.7
Prosser	2,954	2,763	6.9
Wapato	2,841	3,137	-9.4

SOURCE: U.S. Census of Population (1970).

TABLE A6: TOWNS IN THE YAKIMA VALLEY WITH A POPULATION 1000 to 2500

Town	Population 1970	Population 1960	% Change
Union Gap	2,040	2,100	- 2.9
Cle Elum	1,725	1,816	- 5.0
Granger	1,567	1,424	10.0
Villah	1,138	1,059	7.5
W. Richland	1,107	1,347	-17.8
Benton City	1,070	1,210	-11.6
Roslyn	1,031	1,283	-19.6

SOURCE: U.S. Census of Population (1970).

TABLE A7: POPULATION GROWTH RATES IN THE YAKIMA VALLEY: 1960-1970

County	Population 1970	Population 1960	% Change
Kittitas	25,039	20,467	22.3
Yakima	144,971	145,112	- 0.1
Benton	67,540	62,070	8.8

SOURCE: U.S. Census of Population (1970).

TABLE A8: PERCENT OF THE RURAL POPULATION TO THE TOTAL POPULATION IN THE YAKIMA VALLEY: 1960 and 1970

County	% Rural Nonfarm		% Rural Farm		% Change
	1970	1960	1970	1960	
Kittitas	34.8	45.7	10.9	12.2	-10.6
Yakima	35.8	30.9	13.0	17.9	-27.3
Benton	28.8	28.0	5.4	6.7	-19.4

SOURCE: U.S. Census of Agriculture (1969).

TABLE A9: TYPES OF FARM ORGANIZATIONS IN THE YAKIMA VALLEY

County	Type of Farm Organization				
	Independent or Family (%)	Partnership (%)	Corporation (shareholders)		
			< 10	≥ 10	Total %
FARMS					
Kittitas	415 (87.7)	46 (9.7)	10	1	(2.3)
Yakima	2,946 (86.8)	324 (9.5)	95	9	(3.1)
Benton	594 (85.3)	62 (8.9)	34	2	(5.2)
ACREAGE					
Kittitas	108,176 (39.7)	150,952 (33.2)	122,823	180	(27.1)
Yakima	498,025 (59.9)	129,374 (15.6)	194,044	7,322	(24.2)
Benton	392,471 (51.5)	207,114 (27.2)	157,480	886	(20.8)

SOURCE: U.S. Census of Agriculture (1969).

TABLE A10. TENURE OF FARM OPERATORS IN THE YAKIMA VALLEY

County	Type of Tenure					
	Full Owners		Part Owners		Tenants	
	All Farms (%)	Class 1-5 (%)	All Farms (%)	Class 1-5 (%)	All Farms (%)	Class 1-5 (%)
FARMS						
Kittitas	493 (73.1)	323 (68.3)	136 (20.2)	119 (25.2)	45 (6.7)	31 (6.6)
Yakima	3,661 (75.6)	2,383 (70.2)	839 (17.3)	766 (22.6)	345 (7.1)	246 (7.2)
Benton	847 (73.7)	445 (63.9)	220 (19.1)	184 (26.4)	82 (7.1)	67 (9.6)
ACREAGE						
Kittitas	81,427 (15.1)	72,256 (15.9)	309.751 (57.5)	258,710 (56.9)	147,594 (27.4)	123,166 (27.1)
Yakima	1,126,508 (62.4)	161,042 (19.4)	594,182 (32.9)	588,879 (70.9)	83,223 (4.6)	80,805 (9.7)
Benton	93.518 (12.0)	79,609 (10.5)	546,695 (70.3)	545,635 (71.6)	137,081 (17.6)	136,490 (17.9)

KEY: Class 1-5 farms are those farms with sales of $2,500 or more.

TABLE A11. ACREAGE UNDER IRRIGATION IN THE YAKIMA VALLEY

County	ACRES											
	1-9	10-49	50-69	70-99	100-129	140-179	180-219	220-259	260-499	500-999	1000-1999	2000
TOTAL ACRES, FARMS WITH IRRIGATED LAND												
Kittitas	177	2,482	1,271	4,906	4,626	10,320	6,034	8,798	26,184	22,082	20,711	313,087
Yakima	3,177	50,798	19,570	26,538	23,187	27,005	19,126	17,579	59,316	55,118	46,717	319,548
Benton	651	8,760	3,032	6,632	6,829	7,076	4,890	4,236	11,598	17,531		
FARMS WITH ACRES OF IRRIGATED LAND												
Kittitas	108	2,036	903	4,128	3,344	8,726	4,598	5,748	17,098	14,344	5,867	13,909
Yakima	2,789	41,003	15,801	20,117	16,724	19,252	13,622	11,973	43,858	36,826	22,991	20,120
Benton	574	6,726	2,095	5,142	4,874	4,709	3,221	2,963	9,074	10,399		
NUMBER OF FARMS WITH IRRIGATED LAND												
Kittitas	20	102	22	60	39	65	30	37	76	32	15	24
Yakima	551	2,113	336	325	199	171	97	74	172	81	36	33
Benton	115	379	52	81	57	45	25	18	33	25	2	13

SOURCE: U.S. Census of Agriculture (1969).

1 acre = 0.4047 hectares.

TABLE A12. NUMBER OF FARM UNITS PER ECONOMIC CLASS IN THE YAKIMA VALLEY

	ECONOMIC CLASSES															
County	$1-2,499	2,500-4,999	5,000-7,499	7,500-9,999	10,000-14,999	15,000-19,999	20,000,29,999	30,000-39,099	40,000-59,999	60,000-79,999	80,000 *	Class	Part-Time	Part Retirement	Abnormal	Total
Kittitas	16	62	46	47	64	34	84	40	26	17	37	15	155	28	3	674
Yakima	76	639	420	318	432	299	382	224	224	113	268	167	1,085	196	2	4,845
Benton	21	146	76	63	83	61	75	44	43	23	61	48	353	51	1	1,149
Total																6,668

SOURCE: U.S. Census of Agriculture (1969).